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CONTENTS

	PAGE
FRONTISPIECE : FLUORESCENT LIGHTING AT THE COAL FACE	2
ELECTRICAL PROGRESS AND DEVELOPMENT	3
Contributed by members of the Technical Staffs of the Works and Research Laboratories of the Company.	
POWER EQUIPMENT	3
MINING GEAR	12
ROLLING MILLS	13
INDUSTRIAL ELECTRIFICATION	14
TRANSPORTATION	15
ELECTRIC MOTOR DEVELOPMENTS	18
MATERIALS HANDLING	20
ELECTRONICS	21
RADIO AND VALVES	22
MEASURING INSTRUMENTS	26
DISCHARGE LAMPS AND THEIR APPLICATIONS	29
PROCESS HEATING	36
AGRICULTURAL AND DOMESTIC HEATING	40
DEVELOPMENTS IN FACTORY EQUIPMENT	41
GROUND LIGHTING FOR CIVIL FLYING *By H. J. Turner.*	44
STRESSES IN TURBINE WHEELS WITH "CRITICAL TAPER" *By J. M. Mitchell*	50
ELECTRICAL EQUIPMENT IN A MODERN RUBBER MILL PLANT *By F. W. Hayes.*	53

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FLUORESCENT LIGHTING AT THE COAL FACE.

A fluorescent lighting installation at the coal face in Chislet Colliery, Kent.
This is the first of nine demonstration equipments which the G.E.C. is installing under the sponsorship of the National Coal Board.

Electrical Progress and Development

Contributed by Members of the Technical Staffs of the Works and Research Laboratories of the Company.

INTRODUCTION.

THE past year has been one of consolidation. The foundations for peace-time production have been firmly laid, and the industry can confidently confront the tasks demanded of it.

The importance of the electrical industry to national prosperity is now supremely evident. Fundamental requirements such as the generation of electrical power, re-equipment of the mines, modernisation of the textile industry, transportation by land, sea and air, all come within its orbit.

During the year the first of the new post-war power stations was opened. This is the Meaford Station of the North West Midland Joint Electricity Authority, views of which are seen on pages 5 and 6.

The six hydrogen-cooled turbo-generators for Newport Corporation, with a total output of 450,000 kVA, mark a new stage in the design of power plant. Other central station equipment includes two 40,000 kVA sets for Accrington Corporation ; a large extension to the generating capacity of the Steel Company of Wales ; two 25,000 kVA sets for Eire, in addition to a great variety of electrical equipment for Overseas users. Development has proceeded steadily in rectifier plant which is now in use throughout the whole field of industry.

An innovation of great interest in the mining industry has been the installation of fluorescent lighting at the coal face.

The first units of the fleet of trolley buses for Belfast City Transport Department are in operation, and thirty equipments are in hand for Tasmania. The new tappet type of master controller is now coming into service. A diesel-electric locomotive of 1,600 h.p. for mixed traffic duties on home railways is in course of development. The introduction of the system of coded track circuit signalling will add materially to safety on the railways.

Electronic control now occupies an established place in industry, and has been successfully applied to the most intricate operations which it would have been impossible to conduct by other means.

Much has been accomplished in the field of radio, particularly in the direction of safer flying. The radio compass is an outstanding example of what has been achieved.

Electric heating has proved of increasing importance to industry in its simplicity, economy and especially in its adaptability. Recent advances indicate an ever-widening field of usefulness.

POWER EQUIPMENT.

Steam Turbines.

During the year under review, the design of a standard 60,000 kW 3,000 r.p.m. steam turbine, together with the necessary patterns and tools, has been completed. This design complies with the Statutory Rule and Order No. 2386/1947, that is, 60,000 kW as the maximum and most economical rating ; inlet steam pressure to be 900 lbs. per sq. inch ; inlet steam temperature 900 degs. F., the feed water being preheated by bled steam to 385 degs. F. at 60,000 kW output. From the sectional view shown in fig. 1 it will be seen that the turbine comprises a high pressure and a low pressure casing, the latter with double flow arrangement. The inlet to the high pressure casing is adjacent to one of the low pressure exhausts and the blading is designed so that the centrifugal force is balanced by the reaction increasing from root to tip and the distribution of steam during its passage through the stage remains unaltered.

A satisfactory solution of the problem of thermal expansion in a modern high temperature turbine is of prime importance. The special disposition of the two cylinders—an arrangement successfully employed for many years on the standard 30,000 kW turbines—goes a long way towards solving this problem. The easy starting and operational reliability obtained with these machines was the principal reason for its adoption on the 60,000 kW turbine.

The increase in size in comparison with the standard 30,000 kW turbine is chiefly noticeable in the low pressure end ; the area of the blade annulus of the last stage is greatly in-

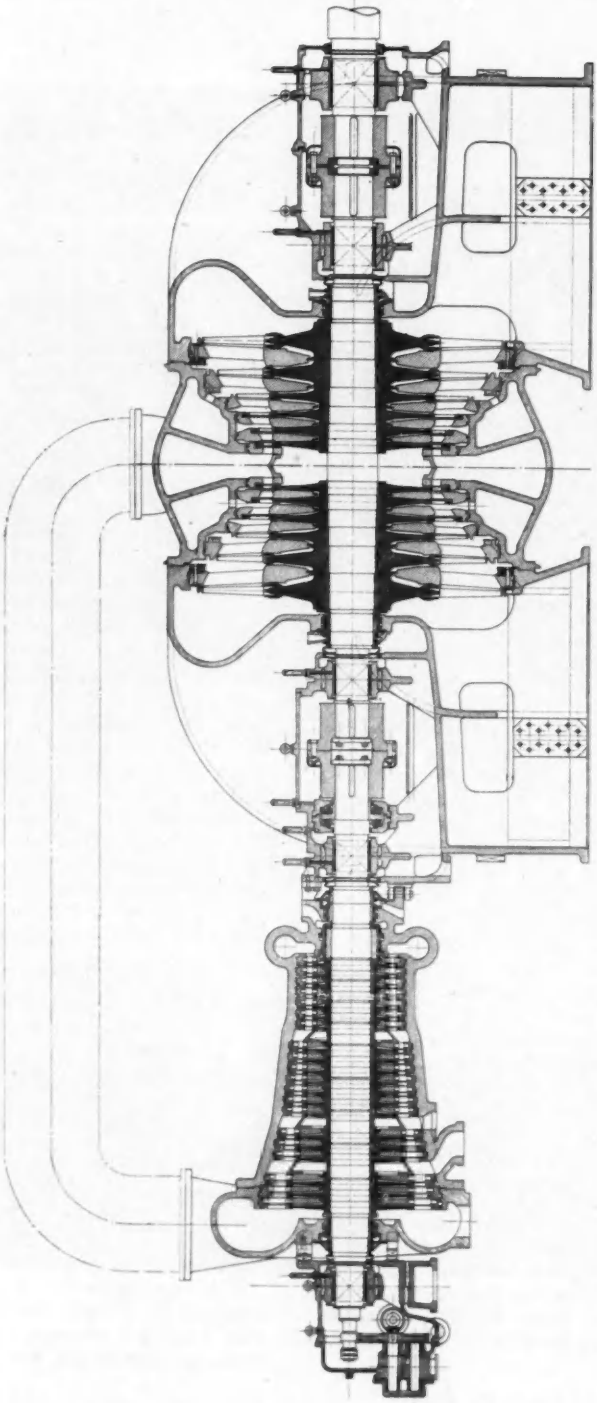


Fig. 1.—Sectional diagram of a 60,000 kW, 3000 r.p.m. steam turbine.

creased by increasing the diameter of the disc and lengthening the blades; the other low pressure wheels are correspondingly increased in diameter. Both the discs and blades are of heavier section to withstand higher peripheral speeds and greater blade loading.

The larger diameter of the low pressure wheels enables a greater heat drop to be used efficiently in the low pressure stages, and, in consequence, the heat drop in the high pressure end is actually smaller than in the 30,000 kW turbine which receives steam at 600 lbs. per sq. in. and 850 degs. F. However, the temperature gradient in the low pressure end of the 60,000 kW turbine is only of the order of 225 degs. F., and thus presents no difficulty. The conditions in the high pressure end are at least as good as in the 30,000 kW turbine, so that there is no reason for dividing it into two parts and making a three-casing turbine with increased gland and bearing losses as well as added thermal expansion complications due to greater length. Service and maintenance are also simpler with a two-casing machine.

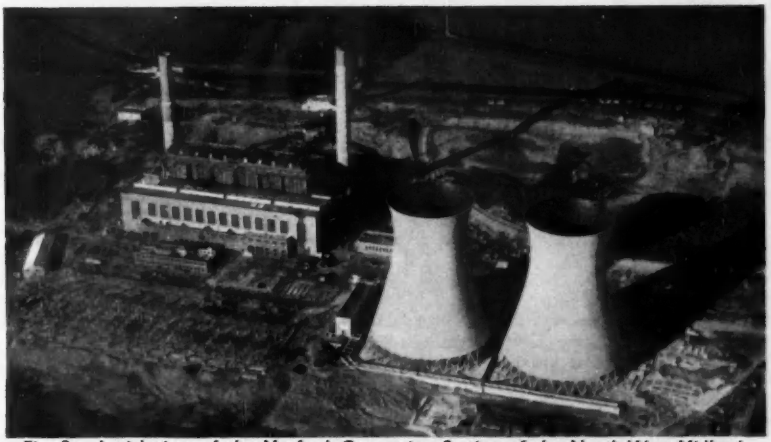


Fig. 2.—Aerial view of the Meaford Generating Station of the North West Midland Joint Electricity Authority. This is the first new station of the Central Electricity Board's programme to be put into commission and has a capacity of 120,000 kW.

Mixed Pressure Governing of Turbines.

Developments have also taken place in mixed pressure governing. To obtain higher efficiency with low pressure steam at partial loads, the steam is admitted by four valves which open in succession. The nozzle cut-out governing with a small heat drop thus achieved is considerably more efficient than simple throttle governing.

Furthermore, the governing operates either under the control of the speed governor or under pressure control. As in the normal mixed pressure turbine, when operating under the control of the speed governor the low pressure steam has preference, high pressure steam being admitted only when there is insufficient low pressure steam to give the required output. When the turbine is operating under pressure control, and therefore in parallel with other plant, the governing admits all available low pressure and high pressure steam up to a limit where it automatically begins to restrict the supply of high pressure steam.

Turbo-Blowers.

To meet the requirements of the increased size of blast furnaces, a new size of turbo-blower has been developed capable of handling up to 90,000 cu. ft. of air per minute against pressures up to 30 lbs. per sq. in. A number of improvements is incorporated in the design amongst which may be mentioned an inlet ensuring uniform distribution of air to the first stage, a diffuser and return channel permitting better conversion of kinetic into pressure energy and a volute and straight diffuser for better utilisation of the velocity from the last stage.

Plant for Home Use.

One of the most interesting orders received during the past year was that for the Usk Mouth Power Station of Newport Corporation which

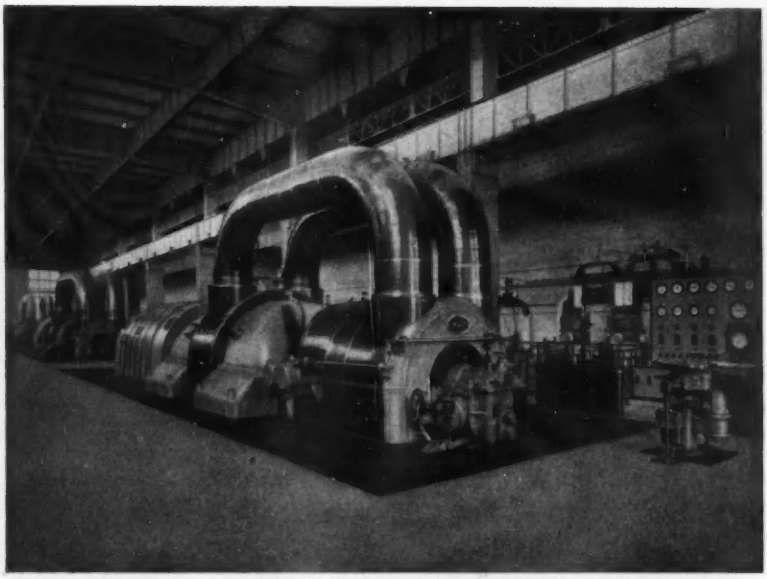


Fig. 3.—The turbine room of the Meaford Power Station, where four 30,000 kW turbo-alternators are being installed. The two sets in the foreground are now on load ; the third set, in the background, is in course of erection.

includes six 60,000 kW standard high pressure turbines each driving a 75,000 kVA hydrogen-cooled alternator at 3,000 r.p.m. The contract also covers switchgear, rectifiers, transformers and auxiliary motors.

For Accrington Corporation, Huncoat Power Station, there are on order two turbo-alternator sets each consisting of a 30,000 kW standard high pressure turbine driving a 40,000 kVA air-cooled alternator at 3,000 r.p.m., together with main and auxiliary transformers, switchgear and auxiliary motors.

A very considerable amount of equipment is on order for the Steel Company of Wales. The more important items include two 10,000 kVA turbo-alternators driven by 8,000 kW mixed pressure turbines and three turbo-blowers driven by back pressure turbines. One of these blowers is to handle 60,000 cu. ft. of air per minute, each of the other two 80,000 cu. ft. per minute against a pressure of 18 lbs. per sq. in. in every case. There are also

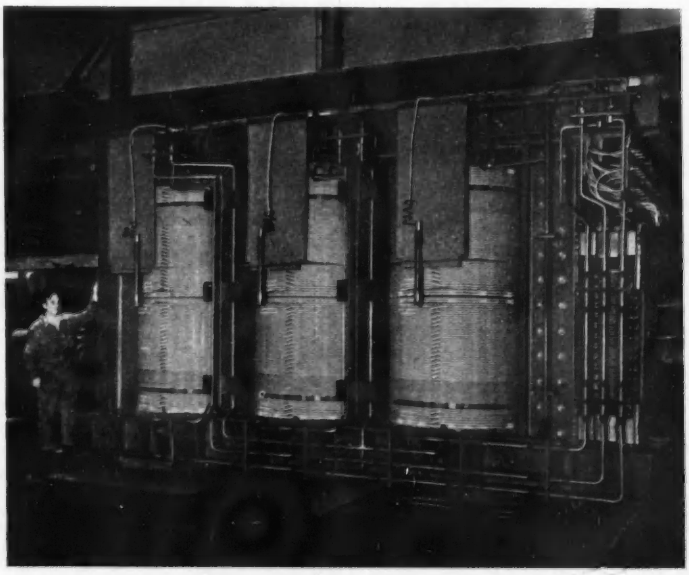


Fig. 4.—View from the high tension side of the 45,000 kVA 132 kV/33 kV transformer for Newport Corporation.

five 1,600 kW rectifier equipments and a large number of motors for driving rolling mill auxiliaries.

The largest turbo-blowers to be installed in this country are two in course of construction for Dorman Long & Co., Ltd. Each is to be driven by a high pressure turbine and capable of handling 90,000 cu. ft. of air per minute against a pressure of 20 lbs. per sq. in. This latest order brings the number of turbo-blowers, either installed or on order for this firm, to a total of twenty-two.

Amongst the plant on order which is required to supply both power and process steam, mention may be made of a 3,500 kW set for Carringrove Paper Mills, Denny, Stirlingshire, comprising a 3,000 r.p.m. pass-out turbine driving a 4,375 kVA alternator. For the Overton Mills of Portals, Ltd. there is a 1,500 kW set in which the pass-out turbine, running at 6,000 r.p.m., drives a D.C. generator through gearing at 600 r.p.m.

EQUIPMENT FOR EXPORT.

An order has been placed by the Eire Electricity Supply Board for two 20,000 kW turbo-alternator sets for the Allenwood Power Station. The turbines are of the single casing type, the inlet steam pressure being 400 lbs. per sq. in. at a temperature of 800 degs. F. The alternators are rated at 25,000 kVA, 10,500 volts, and are required to give their full output over a voltage range of 9,500 to 11,500 volts, and 70 per cent of their kVA rating at zero leading power factor.

A duplicate of the No. 4 generating set installed in the Haifa Station of the Palestine Electric Corporation is on order for the Reading Station. The equipment comprises a two-casing 30,860 kW, 3,000 r.p.m. turbine driving a 40,000 kVA, 11 kV alternator; there is also an 860 kW house service alternator directly coupled to the main shaft.

Following previous contracts for generating plant and mining equipment for Mount Isa Mines, Australia, an additional 12,000 kW, 15,625 kVA turbo-alternator set supplying power at 3.3 kV is in course of manufacture.

An order from Whitehall Securities Corporation for the Athens Electric Co. covers a 4,300 kW, 6,000 r.p.m. back pressure turbine driving an alternator through gearing at 1,500 r.p.m. The turbine receives steam at 900 lbs. per sq. in., 900 degs. F., and exhausts into the existing boiler range at 180 lbs. per sq. in.

Recent orders from India include three geared turbo-alternator sets. For West Bokara Collieries there are two 1,000 kW, 7,000 r.p.m. high pressure turbines driving alternators at 1,500 r.p.m., and for the India Paper Pulp Co., Ltd., a double pass-out 1,875 kW, 6,000 r.p.m. turbine driving an alternator also at 1,500 r.p.m.

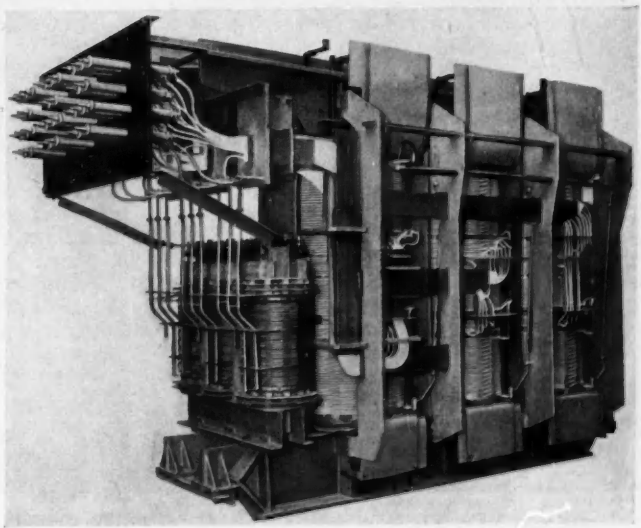


Fig. 5.—12,500 kVA, 66kV/24kV transformer for Palestine Electric Corporation, with on-load tap-changing. View from the high tension side.

From the United Africa Co., Ltd., for the Gold Coast, an order has been received for three 1,000 kW geared turbo-alternator sets, the high pressure turbines running at 7,000 r.p.m. and the alternators at 1,500 r.p.m.; and for Burutu two geared sets each rated at 375 kW. For South Africa, an 1,875 kVA, 3,000 r.p.m. turbo-alternator set is being supplied to the Tongaat Sugar Co., Durban, the turbines being 1,500 kW back pressure machines.

The South African Iron & Steel Industrial Corporation has placed an order for two motor-driven turbo-blowers each to be capable of dealing with 68,400 cu. ft. of air per minute against a pressure of 20 lbs. per sq. in. The motors are 7,000 h.p., 11 kV, two-pole turbo-type machines which are directly coupled to the blowers and designed to run at 3,000 r.p.m.

and to operate at .9 leading power factor.

A number of orders has been received for turbo-compressors for the South African Mines, amongst which may be mentioned three for the Anglo-American Corporation. Two of the compressors are to be driven by high pressure turbines, and each is to be capable of supplying 15,000 cu. ft. of air a minute at 90 lbs. per sq. inch; the third, which will be driven through gearing by a 4,200 h.p. motor, is to supply 20,000 cubic ft. per minute at 80 lbs. per sq. inch. This latest contract brings the number of turbo-compressors installed or on order for this Corporation to a total of nine. For New Consolidated Goldfields Ltd., four compressors are on order, each driven through gearing by a 3,400 h.p. motor, and to be capable of supplying 15,000 cu. ft. per minute at 100 lbs. per sq. in. With these four machines the Company will have supplied altogether twelve turbo-compressors to this client.

For the Argentine, a gear-driven turbo-generator set is in course of construction for Bieckert's Brewery; it comprises a 700 kW pass-out turbine running at 6,000 r.p.m. and driving a D.C. generator at 750 r.p.m.

It will be recalled that details have already been published* of the water-wheel generators being supplied to the Scottish Hydro-electric Board; there is now on order for the Siemens-Oslo Company, Norway, a 3,500 kVA water-wheel generator, 5,250 volts, 500 r.p.m., capable of withstanding an overspeed of 950 r.p.m.

* "Electrical Progress and Development," *G.E.C. Journal*, Vol. XIV., No. 3, February, 1947, p. 125.

Transformers, Reactors and Condensers.

Amongst the large transformers constructed during the year may be mentioned one of 45,000 kVA capacity, 132 kV, for the Central Electricity Board at Newport, Mon. (fig. 4); also one of 37,500 kVA, 11.8/35.1 kV, for Newport Corporation. Further orders from the latter have been received for six 70,000 kVA transformers for the new Usk Mouth Station together with a number of auxiliary transformers of 7,500 kVA and 10,000 kVA capacity.

Several transformers of capacities between 10,000 kVA and 20,000 kVA designed for water cooling, have been built for the Palestine Electric Corporation for operation on 66 kV and 110 kV systems (fig. 5).

During the year a range of transformers for soil warming in horticultural and agricultural establishments has been developed and put into production. Particular care has been necessary in the design and construction of the containers in view of the exacting conditions under which they may be required to operate both as regards the range of humidity and the variations in temperature.

For the Hams Hall Station of the City of Birmingham Electric Supply Department reactors at 90 MVA throughput at 132 kV have been supplied. These are similar to those previously built for the Ocker Hill and Upper Boat Stations.

Mention may be made of the new unit size of capacitor of 100 microfarads, 5 kVA, 400 volts, 50 cycles, which has been developed and put into production.

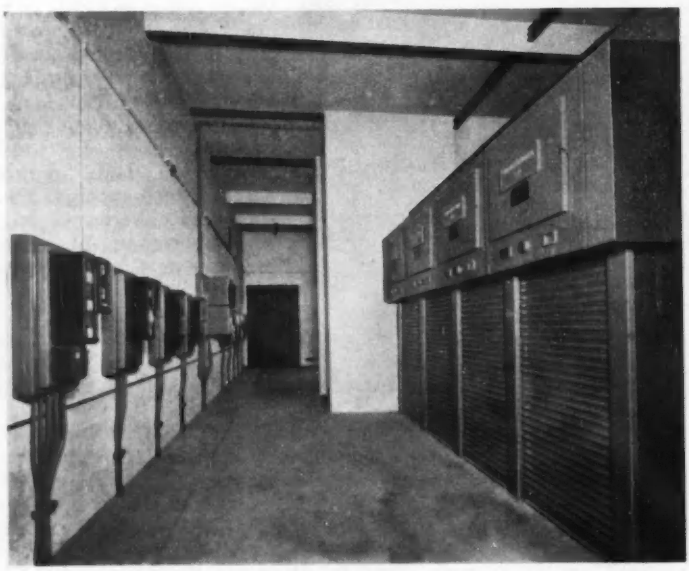


Fig. 6.—33 kV heavy duty metalclad switchgear, 500 MVA breaking capacity, forming part of a nine-unit board at the Eagle and Child Substation, Liverpool.

A three phase bank of 11 kV condensers suitable for connection to the 11 kV overhead system and for passing high frequency signal currents has been designed and built for use in the ripple frequency signalling gear for the Wigtownshire Electricity Company, Stranraer.

MERCURY ARC RECTIFIERS.

Developments in steel tank pumpless rectifier equipment have proceeded steadily, and converting plant covering a wide range of power has been supplied for a great variety of purposes such as the steel and chemical industries, coal mining and traction, as well as for general industrial use and for research establishments.

A notable feature has been the number of installations in the heavy current lower voltage groups; these demonstrate how effectively static converting equipment has displaced rotating plant throughout the entire range of voltage.

Amongst many interesting equipments, mention may be made of the quadruple and twin cylinder units for the 1,000 kW and 500 kW sizes installed at Appleby Frodingham Steel Co., triple cylinder units for Richard Thomas & Baldwins Ltd., and other equipments for English Steel Corporation, Stewart & Lloyds and Sheepbridge Iron & Coal Co. Many are repeat orders; these include multi-cylinder units of the largest size and serve to demonstrate the ability of large cylinders to operate in parallel from the same transformer over a wide range of load.

It is encouraging, at the present time, to record that pumpless rectifiers continue to make progress in the sphere of mining; equipments for various British collieries such as the 1,000 amp. rectifier for Tarini and a similar unit for Wath are typical of such applications. For the chemical industry a 750 kW unit has been supplied to B. Laporte, Ltd.

Amongst important grid controlled rectifier applications are a 1,200 amp. rectifier supplied to Parsons Marine Engineering Research; rubber industries are represented by a triple-cylinder 750 kW equipment for Spencer Moulton; gas industries by a repeat order for a 1,000 amp. single cylinder for Granton Gas Co.; while in the field of engineering a small unit has been supplied to Platt Bros.

Rectifiers of the most modern design embodying the latest technical advances continue to be supplied to overseas markets, including India and Australia.

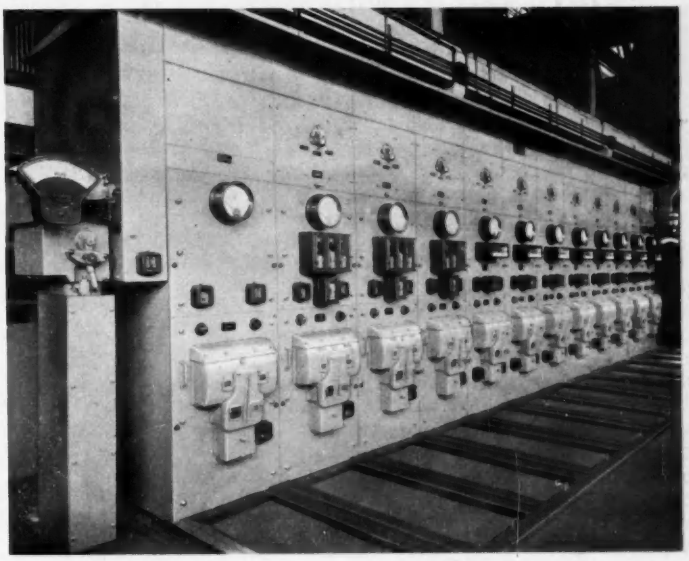


Fig. 7.—3.3 kV truck type switchboard for the Hams Hall Station of the City of Birmingham Electric Supply Department, controlling boiler house auxiliaries of a 50,000 kW unit. This is one of nine boards comprising 120 panels in all.

HEAVY DUTY SWITCHGEAR.

In anticipation of the future needs of industry the range of heavy metalclad switchgear is continually being widened, and designs are now available up to 1,500 MVA breaking capacity at 33 kV, and 750 MVA at 22 kV. A heavy duty 33 kV metalclad board for the Eagle and Child Substation of the Liverpool Corporation is seen in fig. 6. Recent detail improvements have largely been in the direction of increasing convenience in operation and simpler maintenance. Truck type switchgear still occupies a position of importance for power station and similar applications. A large contract for 3.3 kV truck type switchgear for the Hams Hall Station of the City of Birmingham Electric Supply Department has recently been completed. The installation consists of 9 boards comprising, in all, 120 panels. One of these boards is seen in fig. 7.

FUSE TESTING BOARD.

In order to deal speedily and efficiently with

the increasing output of high rupturing-capacity cartridge fuses, particularly the small ones used in the consumer's electricity control units described below, testing facilities have been amplified by the provision of the board shown in fig. 8. All fuse links manufactured are subjected to a routine resistance measurement while carrying full load current, and the new board is designed for making such measurements rapidly on fuse links up to 30 amps. current rating. The fuse link is placed in the jig, which is illustrated in detail in fig. 9, and lowered on to the contacts by means of a treadle mechanism, the resistance being read from the reflecting ohmmeter operating on the translucent scale visible above the ammeter. The supply to the test circuit is 12 volts D.C. derived from rectifiers fed from a voltage stabiliser which eliminates the effect of fluctuations in the mains voltage. Full load current is applied to the fuse link and after a time interval—usually 5 seconds—predetermined by means of an electronic timer, the lamp in the optical system is automatically boosted and the value of the resistance is read as a percentage of the standard value. The equipment affords inherent compensation for temperature variations, so that the resistance value read is not the actual value but that which the fuse link would have if operating in a standard ambient temperature.

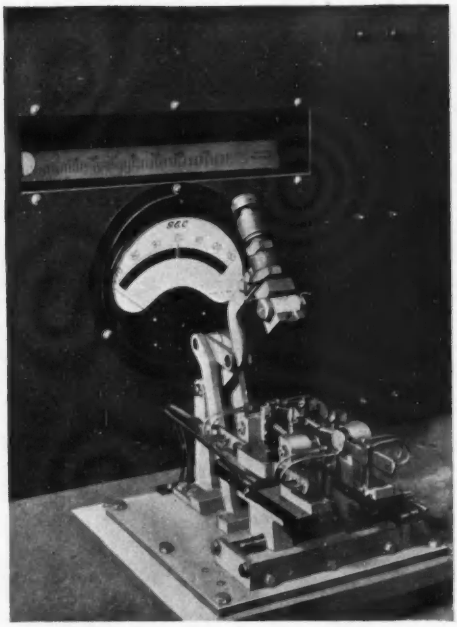


Fig. 9.—Detail view of the fuse jig and the measuring and recording instruments seen in fig. 8.

Domestic Fuse Holders.

A new design of domestic fuses, rated 5, 15, and 30 amperes, has been produced which is suitable for taking the new British Standard cartridge fuse links. The base consists of moulded bakelite carrying the fixed contacts which are so shrouded that when the fuse holder is withdrawn it is impossible to touch the live metal with the fingers.

A 30 ampere fuse holder is seen in fig. 10 both with the cartridge in position and when removed, and it is interesting to note the comparison with the earlier type of H.R.C. fuse holder shown on the extreme left. It will be seen that the fuse holder consists of a single bakelite moulding carrying clips into which the cartridge is inserted without the use of any tools. These clips engage with the fixed contacts in the base when the holder is in the service position. As an additional safety measure, the holder is provided with a skirt so arranged that it is impossible to touch live metal even when the holder is partly withdrawn. A typical consumer's electricity control unit is illustrated in fig. 11, while a fuse box with the cover open, showing four 30 amp. and two 5 amp. fuses, is seen in fig. 12.

Fig. 8.—Testing bench for H.R.C. fuses from 1 to 30 amperes.

Weir Type Liquid Controller.

The latest type of liquid controller which has been developed for use with the largest sizes of induction motors is illustrated in fig. 13.

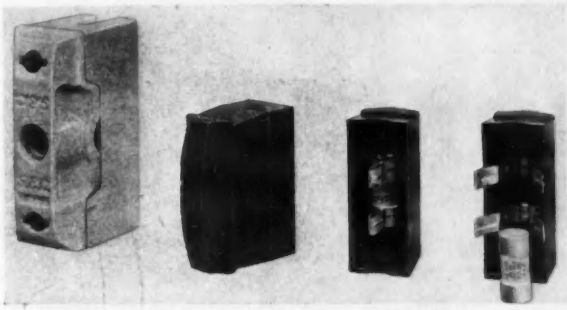


Fig. 10.—The new design of 30 amp. domestic fuse holder compared with the earlier type of 30 amp. H.R.C. fuse holder seen on the extreme left.

It has been evolved from the "weir" type of controller and has several new features which obviate disadvantages associated with the earlier designs.

The usual arrangement is to have fixed electrodes and vary the depth of immersion by varying the level of the electrolyte; but one disadvantage of this design has been the difficulty of obtaining a sufficiently wide variation in resistance. If, for instance, the electrodes are sufficiently close together to obtain the lower limit required, difficulties are experienced when the level of the electrolyte is lowered to reach the upper resistance limit, for, in this position, only the tips of the electrodes are immersed and arcing is liable to occur.

In the new design this difficulty is overcome by moving the electrodes as well as varying the level of the electrolyte, and the moving electrodes themselves serve as the weirs by means of which the level is adjusted. Each phase of the resistance consists of an open-ended trough of insulating material supported on post insulators. One end of each trough is closed by the fixed electrode to the lower end of which is attached a connection through which the electrolyte is pumped by means of external pumps. The movable electrode travels on a carriage running on rails above the trough and is moved to and fro by means of the operating gear. The electrolyte discharges over the top of the trough. One side of the trough is partly cut away so that as the moving electrode recedes further from the fixed electrode the electrolyte spills over at a lower level. The resistance is thus reduced both by the increasing distance between the electrodes and

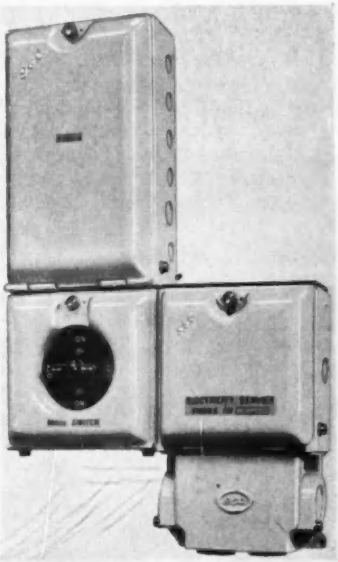


Fig. 11.—A consumer's electricity control unit comprising incoming cable box, main airbreak rotary switch, and distribution fuse box.

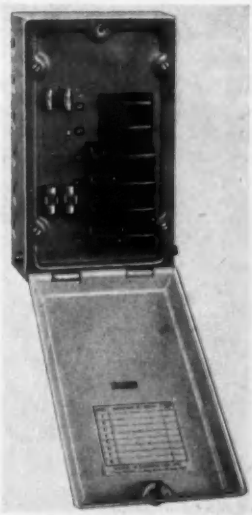


Fig. 12.—Fuse box with cover open, showing four 30 amp. and two 5 amp. fuses. At the left are seen spare fuses for immediate replacement.

the falling level of the electrolyte and consequently shallower immersion of the electrodes.

Both electrodes are provided with ribs which, in the fully closed position, are interleaved, giving a very low value of resistance. In this position the electrolyte enters the narrow passages between the ribs at the bottom and discharges at the top. There is thus very intensive cooling both of the electrodes and of the electrolyte which is carrying the current.

The electrodes and troughs are mounted in the upper part of a large steel plate tank which serves as a reservoir for the electrolyte and carries in its lower portion a cooler through which cold water from an external source is circulated.

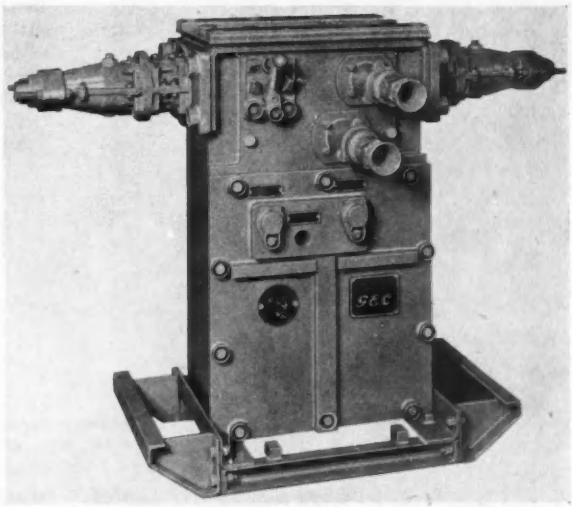


Fig. 14.—External view of coal face lighting panel.

MINING GEAR.

A number of comprehensive contracts for mining equipment for use overseas is in hand at the present time, and the extent and variety of the apparatus which is being supplied, comprising a wide range of both mechanical and electrical gear, renders these orders of more than usual interest.

Overseas Mine Equipment.

The winding installation at the Robinson Deep Mine of New Consolidated Gold Fields Ltd., Johannesburg, is one for which the G.E.C. is supplying the entire electrical and mechanical equipment. The main electrical gear comprises an 1,100 h.p. 525 volt D.C. winder motor 500-0-500 r.p.m. controlled from a Ward-Leonard set consisting of a 1,050 h.p. 2,100 volt slipring induction motor driving an 865 kW, 525 volt D.C. generator at 750 r.p.m.

For the West Bokaro Collieries, India, a comprehensive order is being executed which includes the complete power equipment comprising two 1,250 kVA geared turbo-alternators together with all the requisite switch and control gear, as well as the conveying plant, roll crushers, Chance washery and all the necessary auxiliary motors.

A further comprehensive contract is that for the State Development and Investment Corporation of South Africa. This includes four 4,200 h.p. twin-motor winders each comprising two 2,100 h.p. 6.6 kV slipring induction motors complete with control equipment and employing a new form of dynamic braking designed to meet the specific needs of this installation.

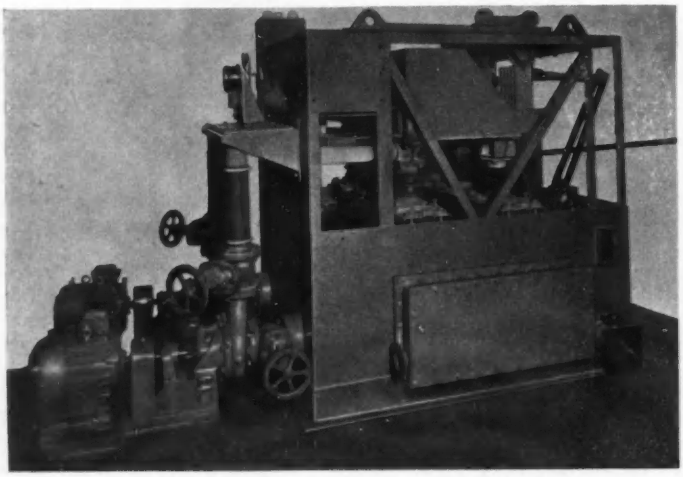


Fig. 13.—The new design of weir type liquid controller.

L FACE LIGHTING PANEL.

The transformer lighting unit, type FLU, n in fig. 14, is designed to give a supply of rent at 110 volts at the coal face, primarily a portable lighting system. The output 2.5 kVA and the panel is designed for use 50 cycle 3 phase A.C. systems ; the primary ding of the transformer has tappings for , 500, 550 and 600 volts. The enclosure, ich is of welded steel, is the same as that d for the gate-end panel described in a vious issue of this Journal.* The lighting el can, therefore, be bolted up to, and form t of, a gate-end switchboard of conveyor l cutter panels. The flameproof construcn complies with the appropriate British ndards and the unit has been certified for in Groups 1 and 2.

AL WASHING PLANT.

As a result of considerable research a froth ation plant has been developed for cleaning e coal, 1/16in. in size, and a pilot plant, on nmercial lines, has been installed at a liery in South Wales, in which fine coal m any coalfield can be tested. Results have ne fully up to expectations and a scheme been submitted to the National Coal ard for mechanically cleaning the whole put of the colliery, thus avoiding any hand ting of coal.

Coal of approximately plus 12 in. in size is broken down to minus 12 in., and the whole of the 12 in. by 1/16in. is cleaned by the Chance sand flotation process of which twenty-one plants are at present in successful operation. The minus 1/16 in. size is screened from the feed with the aid of water on Sherwen electro-magnetically vibrated screens and is delivered direct to the froth flotation plant, where, after cleaning, it is mixed again with the larger sizes.

It is to be noted that during the period under review orders have been received for two coal washing plants for India which will be the first coal cleaning equipment to be installed in that country.

FLAMEPROOF MOTORS.

Re-equipment of British mines will undoubtedly involve an increased demand for a wide range of flameproof motors which is likely to continue for a considerable time in view of the long-term programme already announced. To meet these requirements steady development has been proceeding both in design and in details of construction. Recent additions include 100 h.p. and 150 h.p. fan cooled haulage motors.

ROLLING MILLS.

A complete rolling mill equipment is in course of construction for the Austral Bronze Co. (Pty.), Ltd., Sydney. This is a 20 in. by 60 in. reversing mill for rolling sheets from hot

* *E.C. Journal*, Vol. XIII, No. 3, February, 1935, pp. 114 and 116.

Fig. 15.—Weaving shed at the Swan Lane Mills of Richard Haworth & Co., Ltd., Hindley Green, Wigan. There are 468 Lancashire looms each driven by a 1½ h.p. loom motor through a quadruple V-belt.

copper slabs. The main mill motor is rated at 1,000 h.p. 565 volts D.C., ± 0-30-60 r.p.m., and is a forced ventilated shunt wound machine ; it is supplied from a Ward-Leonard-Ilgner set comprising a slipring induction motor, with an adjustable slip resistance, driving an 850 kW, 565 volt, D.C. generator and a heavy flywheel. An interesting feature of the installation is the control of the two table motors, one on either side of the mill. As this is a reversing mill, the function of each table changes from approaching to delivering, and vice versa, after each pass, so that the speeds of these tables, which are interlocked, must be arranged to conform with the rolling speeds. To this end, the table motors are fed from a generator which is excited from the armature voltage of the Ward-Leonard generator supplying the main mill motor. In addition, a bucking booster is installed to reduce the armature voltage of each table motor alternately as, in its turn, it becomes the driver of the approach table of the mill, thus bringing about the necessary difference in speed between the entry and delivery tables. The booster also is excited from the armature voltage of the Ward-Leonard generator supplying the mill motor, thus maintaining the correct relationship between the speeds of the approach table, the mill and the delivery table. The equipment also includes all the usual auxiliary motors, together with the control gear.

Mention has already been made, in the section "Power Equipment—Plant for Home Use," of the equipment in that category which is being supplied to the Steel Company of Wales. In addition a large number of series wound mill type motors are on order for driving cranes together with some 150 shunt wound motors of the same type for rolling mill auxiliaries. Aggregating some 20,000 h.p. in total capacity, these constitute one of the largest orders of its kind ever to be placed with a British manufacturer. Details of these machines are given below in the section "Electric Motor Developments."

INDUSTRIAL ELECTRIFICATION.

There is in course of construction for Travancore Rayons Ltd., India, the complete power station equipment required for the manufacture of rayon and cellophane. The power plant comprises two 1,875 kVA 3.3 kV geared turbo-alternators together with the necessary transformers, switchgear and auxiliary motors.

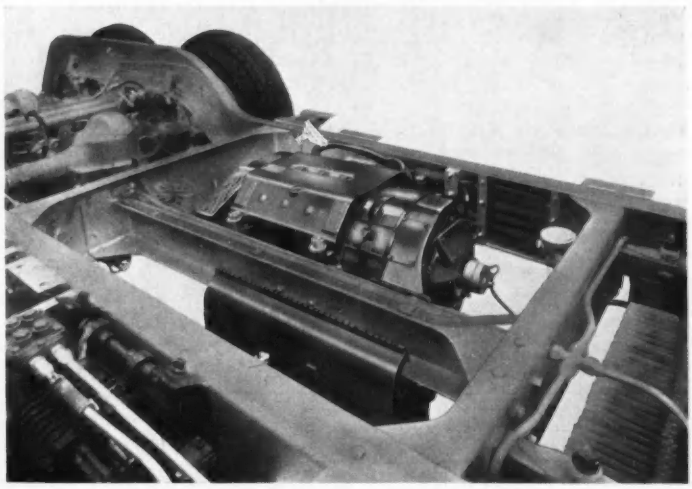


Fig. 16.—A chassis of one of the 182 trolley buses for Belfast City Transport Department, showing the main motor and air filter.

An outstanding example of the most modern type of textile weaving shed at the new Swan Lane Mills of Richard Haworth & Co., Ltd., Hindley Green, Wigan, is illustrated in fig. 15. The West Shed, which forms the subject of the photograph, contains 468 Lancashire looms each driven by a 1½ h.p. loom motor through a quadruple V-belt drive. The looms vary in size from 70 inches to 45 inches, and run at 120 to 180 r.p.m. according to size.

Automatic looms will be installed as soon as conditions permit and the motors are of a suitable size to discharge the heavier duty which will then be demanded of them.

The mill embodies many up-to-date features such as air-conditioning, wide spacing of looms and a colour scheme designed not to distract the attention of employees. The non-glazed portions of the roof are treated with sound-absorbing compound ; all wiring for the motors is run underground, and a separate distribution box is installed for each group of motors.

An interesting installation is that which forms the subject of a contract for Malayan Tin Dredging Ltd. The bucket and mooring winch drives are required to operate under very arduous conditions, and special arrangements have been elaborated to enable them to fulfil these duties. The bucket chain is driven by two 230 h.p. shunt wound D.C. motors connected in series and coupled through a common set of reduction gearing. Power is supplied from a Ward-Leonard set comprising a separately excited 380 kW three-field generator driven by a 6.6 kV 640 h.p. slipring induction motor at 980 r.p.m. The winch is driven by a 35 h.p., 500 volt D.C. motor operating at 750 r.p.m., and it is to be noted that the three-field system of control is similar to that adopted for the D.C. auxiliary motors in the rolling mill installation at the Hawarden Bridge Steel Works of John Summers & Sons Ltd., which was fully described in a previous issue of this Journal.* This method effectively limits the torque developed to about 2½ times full load torque, thus preventing excessive armature current even if the motor should stall, thereby safeguarding the motor against the possibility of damage.

A further overseas order of interest concerns the provision of a heavy current motor-generator set for Bamag Ltd., to be used with an electrolytic plant in Iceland. The equipment comprises two D.C. generators connected in parallel and driven in tandem by a 2,150 h.p. 6 kV slipring motor at 590 r.p.m. The generators, which are separately excited, have a voltage range of 90/200 volts and 200/224 volts, and the total current available is 6,666 amps. The contract includes the starting and control gear and two D.C. panels will be provided to permit individual or parallel operation.

For the Associated Cement Co. Ltd., of Bombay, a number of large synchronous induction motors are in hand for operating a cement works. These include eleven 800 h.p. 3.3 kV, 750 r.p.m. motors and five machines of the same type rated at 450 h.p., together with all the necessary control gear.

A complete installation for the generation and distribution of power is on order for a film company, British Lion Studios Ltd., Shepperton. The equipment includes a motor-generator set comprising a 1,000 kW 3-wire D.C. generator to supply current at 120/240 volts, driven by a 1,450 h.p. 11 kV synchronous induction motor. All the necessary A.C. and D.C. control gear is included, together with means of distribution to the various studios for power and stage lighting, with requisite individual control panels.

* The Electrical Drive of Rolling Mill Auxiliaries," *G.E.C. Journal*, Vol. XIV, No. 4, August, 1947, p. 215.

TRANSPORTATION.

Trolley Buses.

An account of the various contracts in hand

Fig. 17.—One of the Belfast Corporation trolley buses in front of the Parliament Buildings of Northern Ireland.

for trolley bus equipments for Cardiff and Belfast appeared in an earlier issue of this Journal.*

Several of the 70 equipments on Guy Motor chassis for Belfast City Transport Department are now in service. They are of the non-regenerative type with rheostatic braking, and

Fig. 18.—The control gear in the driver's cab of one of the Belfast trolley buses.

employ motors rated at 105 h.p. Fig. 16 shows the motor and air filter mounted on the chassis, while the general appearance of the trolley bus can be seen in fig. 17. It may be added that 24 equipments of the fully regenerative type are in course of erection on B.U.T. chassis.

An interesting order has been received for 30 trolley bus equipments for Launceston, Tasmania, and it is worthy of note that these are the first to be fitted to the special overseas type of chassis manufactured by B.U.T. The design of this chassis necessitates the control gear being mounted at the rear of the bus, and a suitable type of panel and case has been developed accordingly. Service requirements demand a considerable increase in the capacity of the main contactors, and this has been achieved without increasing the size of the standard contactor. The motors are rated at 125 h.p. operating non-regeneratively; rheostatic braking is employed and is controlled by the driver's brake pedal. It is to be noted that an order has since been received for 24 similar equipments for Hobart, Tasmania.

Development of the tappet type master controller (fig. 18), has continued and a master controller of this type installed in a Birmingham Corporation trolley bus has been in service since early in 1947. The tappet master controller differs from the standard drum sector type in respect of the master contacts which are of the butt type and made of silver; the movement of the elements from step to step is absorbed by springs, thus eliminating all sliding friction. The design also embodies the latest methods of insulation and the modern type of reverse drum and fingers.

Modifications in the design of trolley bus motors now make it possible to rate the large type of motor up to 145 h.p. at 600 volts at the one-hour rating. This rating has not yet been exceeded in a single trolley bus motor in this country.

Diesel-electric Developments.

In the course of the year the question of diesel-electric traction has achieved prominence. Considerable interest in its possibilities has been displayed by railway undertakings both at home and abroad, and the special requirements of this form of traction have been given the closest study. It was early decided to build, in conjunction with the North British Locomotive Company, a demonstration diesel-electric locomotive of 1,600 h.p. rating for mixed traffic duties on the home railways. This locomotive, which is of the double six-wheel bogie type, is equipped with four geared traction motors, forced ventilated, and is to be capable of hauling freight trains up to 950 tons at 30 m.p.h., and passenger trains of 345 tons at 75 m.p.h.

The control gear is of completely modern design and includes special heavy duty electro-pneumatic contactors which have been developed since the termination of the war. A driving position is provided at both ends of the locomotive with the controls arranged so as to afford the driver the maximum comfort and convenience. The diesel engine is started by motoring the main generator from the large storage battery; speed control of the locomotive is obtained by varying the speed of the diesel engine under electro-pneumatic control. Special arrangements are necessary to avoid overloading the engine; this is achieved by controlling the generator field regulator through a servo-mechanism actuated by the engine governor in such a manner that the output curve of the generator follows substantially the constant power curve of the engine over the whole range of locomotive speeds.

* *G.E.C. Journal*, Vol. XIV, No. 3, February, 1947, "Electrical Progress and Development."

An auxiliary generator driven by the main engine provides a supply of electric power for charging the battery, operating the compressor and other auxiliary machines, as well as for lighting and control circuits.

Another demonstration diesel-electric locomotive of generally similar design for hauling express passenger trains at speeds up to 100 m.p.h. is in course of construction.

General Development.

Development has also proceeded on equipment for locomotives and multiple unit stock for 1,500 volt and 3,000 volt D.C. operation.

Close attention is being given to the use of silicone insulation in the construction of traction motors. A battery vehicle motor with this type of insulation is already in service, and certain traction motors and generators under construction for railway duty will also have silicone insulation. At present the purpose in employing this type of insulation is mainly to secure longer life and greater reliability, but when further service experience has been accumulated it is confidently expected that higher ratings will be possible without increase in the size of machines.

Railway Signalling : Coded Track Circuits.

Recent developments will enable a saving to be made in the number of line wires required for railway signalling schemes, as well as affording greater safety for the trains.

The basis of all modern signalling is the track circuit : a length of track insulated from the adjoining track by means of insulated block joints. Current is fed into the rails at one end and a relay is connected to the rails at the other end. So long as the current flows the relay is maintained in its "energised" position. When a train enters the track the wheels short circuit the rails, the supply to the relay is interrupted and the relay "de-energises." Thus the position of the relay indicates whether or not the track is occupied, and the relay can, therefore, be used to ensure that a train is not admitted to a section of the track already occupied.

Track circuits are, in general, used only to indicate the state of the track. To control the signals and select the proper aspect required—red, yellow, double-yellow or green—a number of line wires running from signal to signal has been necessary. With a coded track circuit the energy fed into the track is in the form of pulses at the rate of 75, 120 or 180 per minute. Three selective relays at the far end are so arranged that each will respond to one of the codes only. The track circuit itself is thus capable of indicating four different "states," namely, track occupied (relay de-energised) and three states of track clear, corresponding to the conditions permitting the giving of a green (180 code), double-yellow (120 code), or yellow (75 code) signal indication. The coded track circuit in itself and without any additional line wires is thus capable of exercising the necessary signal-to-signal control for three- or four-aspect signalling.

The apparatus employed is simple and robust, utilising the frequency of oscillation of mercury columns in tubes of varying length to produce the differing codes. At the relay end of the track the code impulses are applied to three sets of similar tubes, one only of which, being of the correct frequency, will respond. A notable characteristic of the equipment is the exceptionally small amount of power which it

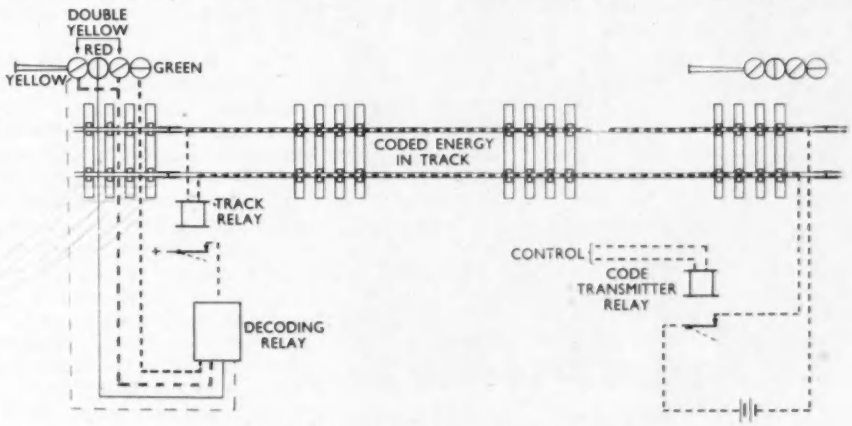


Fig. 19.—Coded track circuit : explanatory diagram.

takes from the track, something of the order of 5 milliwatts only. Apart from the economy in line wires, the coded track can be operated over a greater length and with better reliability than the ordinary track circuit. An explanatory diagram of the coded track circuit is reproduced in fig. 19.

Track Welding Equipment.

For track welding on the city's tramway system a portable motor-generator welding set has been supplied to the City of Edinburgh Transport Department. It consists of a four-operator equipment mounted in an enclosed lorry and designed to supply 300 amps. per operator at 60 volts. A 66 h.p. motor supplied from the 500/600 volt traction supply drives a generator which is separately excited from a 220/270 volt belt driven exciter. The set runs at 1,310/1,500 r.p.m., and the generator voltage is held constant to within $\pm 1\frac{1}{2}$ per cent. For this purpose special windings are incorporated in the exciter field and an automatic voltage regulator is employed. The provision of the special windings serves to reduce to a minimum the duty imposed on the voltage regulator.

A typical multi-operator welding equipment at Milner's Safe Co., Ltd., Speke, is illustrated in fig. 20.

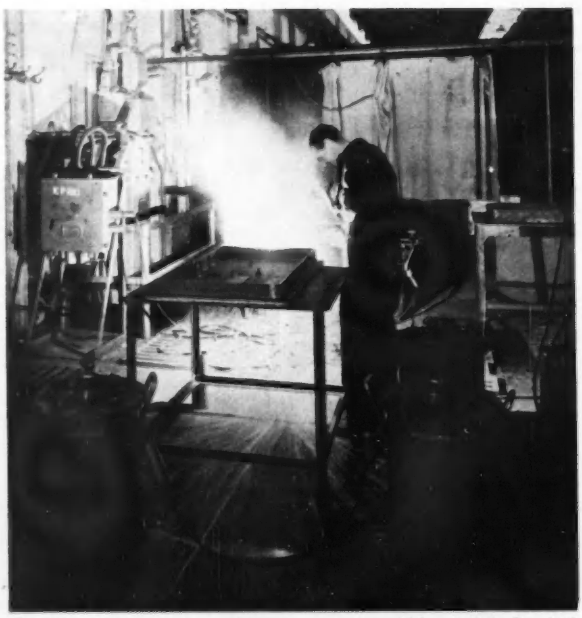


Fig. 20.—A 12-operator welding equipment at Milner's Safe Co., Ltd. The transformer is rated at 360 kVA, 400/100 volts. Three of the portable current regulating reactors are seen in the foreground.

Ship Lighting Equipment.

For the off-shore lighting of ships in dock, seven mobile motor-generator sets have been supplied to the Southern Railway. The generators are flat compounded and give an output of 50 kW at 110 volts D.C. The motors are 77 h.p. machines supplied from a three-wire D.C. system and run at 1,050 r.p.m. Each set with its switchgear and cables is conveniently housed in a weatherproof kiosk which is mounted on a mobile road trailer suitable for towing.

ELECTRIC MOTOR DEVELOPMENTS.

Fractional Horsepower Motors.

During the year a large amount of work has been devoted to overcoming the effects of the shortage of various materials for the purpose of maintaining production. This has led to the adoption of oil retaining bushes in place of ball-bearings, as, for example, in the latest model of floor polisher, also to the greater use of wrapped steel bushes lined with sintered lead-bronze powders.

Direct current fractional horsepower motors of the $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$ and 1 h.p. ratings have been redesigned and brought into line with the new single and three phase ranges introduced last year. The new motors, while conforming with B.S. 170/1939, are both smaller and lighter than the previous equivalent frames, incorporating die-cast aluminium brackets, with improved accessibility to the brushgear and slotted feet making the use of slide-rails unnecessary. Production is now in progress and the first deliveries are expected in the near future.

A new flush design of regulator has been introduced for the Kingsway type of ceiling fan; it is so arranged that, if required, it can be supplied with condensers for power factor correction. The whole regulator and condenser, together with the switches, is mounted in a steel box which can be sunk in the wall, and the front is a moulded bakelite plate carrying the regulator handle and the fan switches. If condensers are not required, a lighting switch can also be incorporated.

The Fractional Horsepower Motor Department is also responsible for

battery charging rectifiers, and, a range of industrial units has been developed in addition to a small domestic charger ; both types employ a selenium rectifying element.

The range of industrial chargers includes one, two and three circuit models with

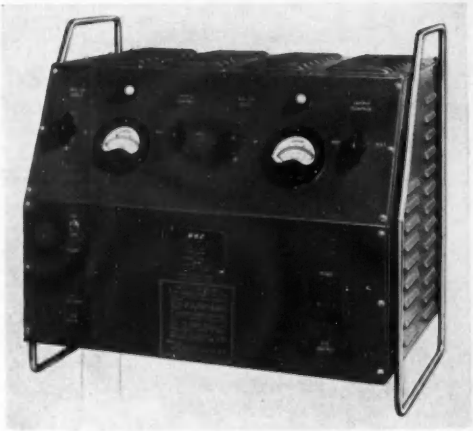


Fig. 21.—The two-circuit industrial type battery charger.

capacities from 6 to 84 cells and charging rates from 2 to 20 amperes. Intended for standing on a bench, the cases have sloping instrument panels, fig. 21, on which are mounted the meters, pilot lamps and output control switches, while below, the D.C. terminals and input and output fuses can be seen.

The domestic unit, known as the home charger, now available, is designed primarily for the private motorist to charge a 12-volt battery at 2 amperes; alternatively there are tappings enabling a 2- or 6-volt battery to be charged.

An interesting device included in the home charger is the combined thermally operated cut-out and indicator. The cut-out protects the transformer and rectifier against excessive overload or accidental short-circuiting of the output leads and is fitted with a pointer passing over a scale reading "low," "medium" and "high," indicating the relative output of the charger.

Mill Type Motors.

As mentioned in an earlier section dealing with Rolling Mills, orders are in hand for D.C. mill type motors for the Steel Company of South Wales aggregating almost 20,000 h.p.

Constructed to the dimensional standards of the American Association of Iron and Steel Electrical Engineers, the motors are built to withstand very severe conditions of service. To resist high ambient temperatures, glass insulation and high temperature varnish are extensively used, and the design is such that sparkless commutation is ensured during heavy overload and under reversal.

The motors embody a number of other special features. An operating voltage of 400 has, in this instance, been adopted instead of the more usual 230 volts in order to keep down the size of cables, switchgear and particularly of the crane trolley wires. The steel shells are split horizontally and all connections are brought out to external terminal boxes of cast steel fitted with heavy steel cover plates. Terminals are arranged for the reception of "Pyrotenax" cable.

Motors between 75 h.p. and 200 h.p. are forced ventilated enabling the nominal output to be developed continuously within the specified temperature rise. Provided with double shaft extensions so that they can drive from either end, the motors take in air through a machine-faced opening under the commutator end of the frame, and discharge it through louvres above the centre line at the opposite end. For purposes of interchangeability and to enable the position of the motor to be reversed end for end, two air outlets from

Fig. 22.—Control desk for distribution section of iron ore handling plant at Stewarts & Lloyds, Corby.

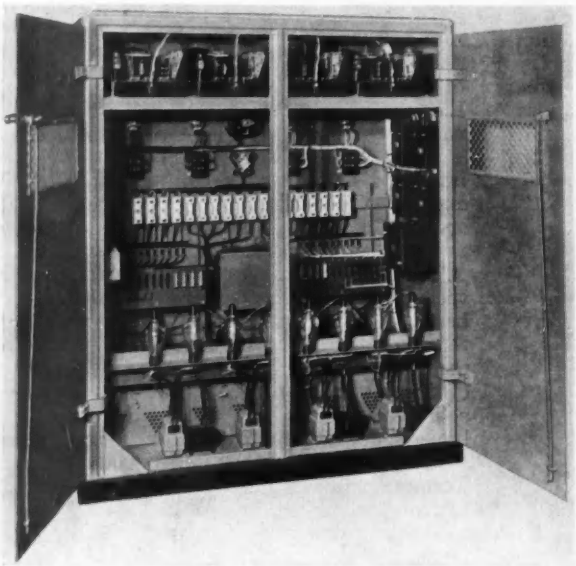


Fig. 23.—Rear view of the electronic control cubicle of the mixing plant for Imperial Chemical Industries.

the ventilation duct are provided on each bedplate corresponding with the alternative positions of the motor inlet under these conditions. A coverplate seals the outlet not in use. Motors which are not required to be ventilated carry totally enclosing covers over inlet and outlet.

Another feature of interest concerns the protection of all shunt windings by voltage-dependent discharge resistors fitted within the motor carcase.

MATERIALS HANDLING

The mechanical handling of materials covers so wide a field that in almost every individual installation some innovation involving originality in design is called for. Belt conveyors figure prominently in most installations and it is worth recording that during the past year manufacture of a complete new range of conveyor idlers has begun on a mass production basis. They embody the latest type of well-proven American design and have met with favourable reception; already, substantial orders are in hand for these components. The types now being produced include troughing idlers, return idlers, rubber-disc cushion idlers and rubberdisc return idlers.

For the first named of these, the new standard arrangement will involve three pulleys instead of five as at present. The pulleys will be of all-steel construction and will run on Timken taper roller bearings of liberal size. "One shot" lubrication is arranged for application at both ends. Grease is retained within and around the bearings by means of patented triple grease seals. The supporting brackets for the pulleys are of malleable iron of great strength and resistant to fatigue and breakage. Similar pulleys, bearings and seals are used for the return idlers.

Where the impact of loading is severe rubberdisc cushion idlers are fitted. These consist of pulleys built up of a number of closely spaced hammer head section rubber discs mounted on a steel tube and so spaced as to permit the full free play of the rubber when cushioning the impact of heavy loads. By this means the life of both surfaces of the rubber belt is prolonged.

Fig. 24.—A grinding machine for ball bearings. The electronic control gear is compactly housed in the base of the machine directly below the handwheel.

Where the material being handled is of a damp, sticky, abrasive or corrosive nature the rubberdisc return idler is suitable. This design of return idler reduces the tendency of sticky materials to build up on the belt face, while corrosive material will not harm them. They consist of resilient, flexible rubber discs carefully spaced along a steel shaft in such a way that the material cannot build up between them. Extra support is given at the edges of the belt and the rubber-to-rubber contact naturally reduces wear.

Brief particulars have been recorded in a previous issue of this Journal* of the ore bedding and blending plant which is being installed at the Corby Works of Stewarts & Lloyds, Northamptonshire. A view of the control desk for the distribution section of this plant is seen in fig. 22.

ELECTRONICS

Control of a Milling Machine.

Electronic control has been successfully applied to the control of a small motor driving the table of a vertical spindle milling machine. The equipment comprises a standard 220 volt D.C. motor, main transformer, control cubicle and the operator's control unit. A speed range of 15 to 1 is provided by control of the armature voltage with a fixed field. The controller provides a pre-settable constant armature voltage with I.R. drop compensation and armature current limitation. Control is effected by means of "forward," "reverse" and "off" push buttons, and a speed controlling potentiometer. It should be noted that the motor is protected against excessive current for, on pressing the "reverse" button, motor reversal is effected under controlled armature current. The arrangement is also foolproof as, if more than one button is pressed, the motor is brought to a standstill without injury.

Fig. 25.—The Miles Gemini aircraft which is used as a flying laboratory.

Conveyor Control.

A system of electronic control has been devised and constructed for a large chemical factory in the North of England. Four different components have to be fed to a main mixing machine, and it is important that the correct proportion of each shall be strictly maintained. The function of the electronic equipment is to control the individual motors driving the four conveyors, each of which feeds one ingredient to the mixer.

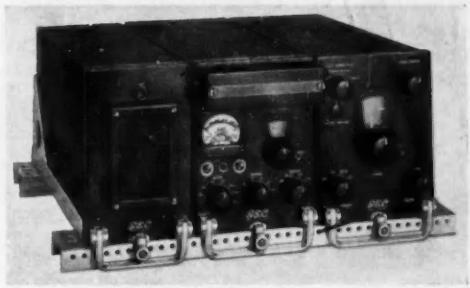


Fig. 26.—H.F. transmitter/receiver and power pack for airborne use.

A master speed controller varies the speeds of all four conveyors simultaneously while maintaining the ratio of the four speeds constant at whatever value has been set by the individual controls. A rear view of the control cubicle is seen in fig. 23.

The motors are ½ h.p. D.C. machines supplied from the A.C. mains, and each is provided with an electronic controller which comprises a presettable constant voltage bi-phase valve rectifier embodying adjustable armature I.R. drop compensation and current limitation. The speed of each motor can be pre-set, and individual push button starting is provided.

Electronic Control of a Wind Tunnel.

One of the most interesting and ingenious applications of electronic control is that supplied to Vickers Armstrong & Co. for the precise control of the air velocity in a wind

* *G.E.C. Journal*, Vol. XIV, No. 3, February, 1947, "Electrical Progress and Development," p. 133.

tunnel. The main fan drive is from a D.C. motor supplied from a Ward-Leonard set. The velocity of the air is measured by means of Pitot tubes which are connected to a manometer, delicately suspended in such a manner that it tilts when the pressures on the two legs are unequal. Weights added to a pan attached to one leg counterbalance the manometer for the desired pressure difference. Also attached to the manometer is a small laminated bar-type armature which moves between two fixed coils which constitute two legs of an A.C. bridge.

Fig. 27.—The component units of the radio compass. (a) Control panel (1). (b) Junction box. (c) Loop aerial in flat housing. (d) Motor driven shaft with differential and mechanical quadrantal error corrector cam at base. (e) Control panel (2). (f) Receiver. (g) Navigator's compass. (h) Cathode follower matching unit. (k) Pilot's repeater indicator.

When the manometer is perfectly balanced there is no output from the bridge. Displacement results in an output, the phase of which is dependent upon the sense of the displacement. The output from the bridge is applied to the grids of an arrangement of two valves, the anodes of which are also supplied from an alternating current, which is termed a "phase conscious amplifier." The output from this is direct current the polarity of which is dependent upon the phase of the alternating current supplied to the valve grids. The direct current output is used to control two large valves, each normally biased to "cut off." Thus displacement of the manometer causes one or other of the last mentioned valves to conduct current. The determination of which valve conducts on any occasion depends on the direction of the displacement of the manometer.

These valves control the currents in the armatures of two fractional horsepower motors geared to the fine regulator of the Ward-Leonard generator and rotating in opposite directions. Thus any error in air velocity in the tunnel causes a displacement of the manometer, which in turn causes the fine regulator of the Ward-Leonard set to move in such a direction as to correct the error.

It is worth recording that the performance of this system of control has been most satisfactory in every way, the application of electronic control in this instance affording the smooth and rapid operation desired.

Grinding Machine.

In an earlier record of progress in this Journal* some particulars were given of electronic control as applied to a grinding machine built by B.S.A. Tools Ltd. for Lucas's. It is now possible to include an illustration of two of these machines in service (fig. 24). The neat and compact manner in which the control gear is housed in the base of the machine is clearly shown.

Radio and Valves.

Radio Communication.

Important investigations are now being made in the aircraft communication and navigation fields, and in order to obtain reliable information on the performance of equipment under normal operating conditions the G.E.C. has fitted out its own aeroplane as a flying laboratory (fig. 25).

An important development in the field of communication is the light weight single channel transmitter/receiver. The transmitter has an output of 0.5 watt and provides for two-way communication up to a range of 20 miles on any one frequency between 118 and 132 Mc/s. The set is very small—measuring 4 ins. wide by 8 ins. high by 9½ ins. deep—and weighs only 8½ lbs.

Fig. 26 shows another airborne equipment for the frequency range 2 to 9 Mc/s. giving

* "Electrical Progress and Development," *G.E.C. Journal*, Vol. XIV, No. 3, February, 1947, p. 135.

an output of 25 watts. The transmitter operates on any one of six crystal controlled frequencies which are selected by means of a switch.

In the aircraft navigation field the development of the instrument landing system, which comprises a glide path receiver operating in the band 329 to 355 Mc/s. and a localiser receiver operating between 108 and 118 Mc/s. is now nearing completion. The equipment enables an aircraft to approach the airport in very bad weather.

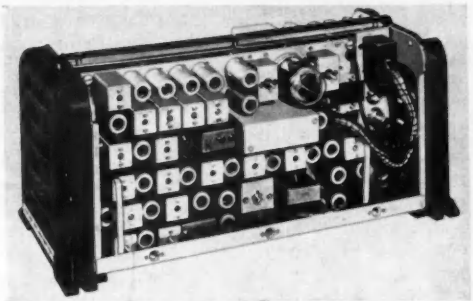


Fig. 28.—V.H.F. transmitter/receiver with cover removed.

Another important new instrument is the radio compass, fig. 27, which has been designed in collaboration with R.A.E., Farnborough, primarily for use in modern high speed aircraft. It determines the aircraft's position and course by means of information derived from ground transmitting stations whose location is known. Special attention has been paid to reducing weight and external projections to a minimum.

For point-to-point communication a new, very compact V.H.F. mobile transmitter/receiver has been introduced which is suitable for either amplitude or frequency modulation (fig. 28). It operates on a single predetermined frequency between 30 and 170 Mc/s., the output being between 15 and 20 watts. Both transmitter and receiver are crystal controlled. The transmitter can be used to drive another unit which gives an output of 100 watts, while this in turn can drive a third unit to give 500 watts output.

One of the most important single projects engaging the attention of the Research Laboratories is the design of a radio link for operation between London and Birmingham. This is to be a complete relay system suitable for operation for many years, and having all the refinements of automatic control previously associated only with permanent cable systems.

The radio frequencies used will be of the order of 1,000 Mc/s. and the system has been designed to operate over optical paths between stations up to forty miles apart. At each station there will be a lattice steel tower 80 ft. high, carrying the radio equipment and the 12 ft. diameter transmitting and receiving aerial systems (fig. 29). The system has been developed round a series of Osram disc seal triodes, including the ACT 22 and ACT 23, which are used as the R-F oscillators and amplifiers at each station.

The immediate purpose of this link is to convey the 405-line Alexandra Palace Television programme to the proposed Birmingham television station and later to allow programmes to be transmitted in the reverse direction. Its importance to the future of long distance communications as a whole is, however, considerable for its techniques are readily adaptable

Fig. 29.—A model of an intermediate station for the London-Birmingham radio relay link.

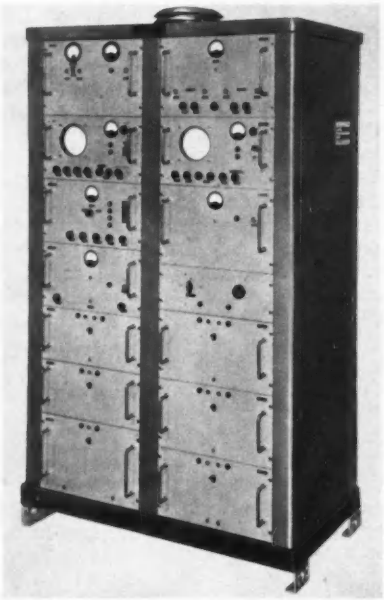


Fig. 30.—Picture test equipment for television receiver design and servicing.

to multichannel radio telephony. For this it may, in certain places, have real advantages in capital cost, in speed of installation and in operational flexibility, over alternative methods.

So far as it known, it is the first comprehensive radio system which has been designed with a chain of unattended stations, a full remote switching and supervisory control-system, automatic fault-indication and automatic changeover to stand-by apparatus, and will give most valuable full-scale experience of the principles involved.

Until this link is in operation, the only suitable signal available to carry out satisfactory tests on complete television receivers is that radiated by the London Television Station at Alexandra Palace. The use of this signal is limited to the London area and to certain periods during the day. In order to overcome these limitations a picture test equipment has been designed. This comprises essentially a miniature 405 line television station of low power output and provides a modulated 45 Mc/s. signal as well as a video signal. The complete equipment, with its power supply unit, is housed in two 6 ft. racks built into a cubicle as shown in fig. 30.

Many radio relay operators are now bringing their equipment up to date to meet modern conditions. The first of the many G.E.C.

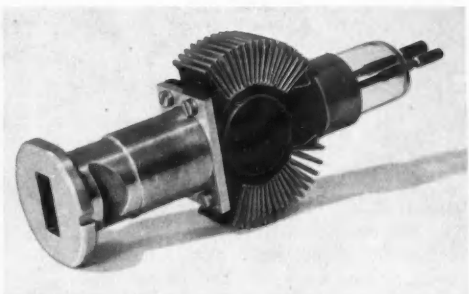


Fig. 32.—High power 3 cm. magnetron.

Fig. 31.—Delayed action key for teleprinter use.

installations to be modernised is the Accra Control Station, Gold Coast, West Africa. This equipment provides a high quality radio relay programme with an audio output of 2,000 watts.

In the teleprinter field, the new delayed action key has been introduced. The key transmits a signal of predetermined length to recall the switchboard operator and to give a clearing signal at the end of a transmission. The mechanism is shown in fig. 31. Depression of the keyhandle operates a set of contact springs to transmit the signal and also winds up a clock spring. The return of the key to normal is controlled by a governor and intermediate gearing operated by the clock spring. The return speed is adjusted to limit the duration of the signal to approximately five seconds.

Quartz Crystals.

During the past year the technique of

mounting quartz crystals by metallising and soldering to fine wires has been improved considerably. Experimentally the frequency range covered by crystals of this type has been extended down to 1 kc/s. In addition to these oscillator crystals two new types have been produced for use in narrow band intermediate frequency filters at 465 kc/s. and 1.6 Mc/s. The selectivity obtained by these crystals is such that an unwanted signal differing from the carrier by only a few hundred cycles per second is down by more than 45 db. on the wanted signal.

Further experience of the process for the removal of electrical twinning from quartz has revealed that a small percentage of crystals do not respond in the normal way to treatment. Investigation has thrown new light on defects in quartz which may be of practical importance.

Experiments on the preparation of synthetic quartz are continuing with the main objectives of improving the reproducibility of the process and the quality of the crystals obtained.

Valves and other Electronic Devices

Work in the transmitting valve field has been mainly directed towards obtaining higher pulse powers for radar purposes and higher continuous wave powers for communications. A magnetron capable of generating an output of 2 megawatts in 1 microsecond pulses at a wavelength of 10 cm. has been developed. Another for operation at 3 cm. wavelength is shown in fig. 32. This gives an output of nearly a quarter of a megawatt with an efficiency of 45 per cent, the pulse length being 0.25 micro-second. The valve is air-cooled and the output system connected directly to a standard waveguide.

Magnetrons are also being developed to give continuous wave powers ranging between 10 watts and 1 kW for communication and industrial heating applications.

For frequencies up to about 1,000 Mc/s. a complete range of triodes now exists which are capable of amplifying small signals through successive stages to give a final output of 300 watts. The outputs at 750 Mc/s. of the four valves are 5, 20, 75 and 300 watts respectively, and each valve is capable of driving the next larger valve of the series.

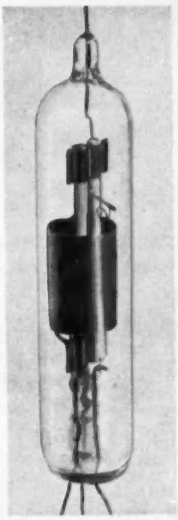


Fig. 34.—Experimental miniature electrometer triode.

The usefulness of existing amplifiers for frequencies above a few thousand megacycles per second is limited by low gain and narrow bandwidth. The travelling wave tube, invented by Kompfner at Oxford, appears to offer possibilities in this field of application and active investigations are in hand. In one form this device consists of a long helix of wire along the axis of which an electron beam is projected (fig. 33). A high frequency signal is injected at one end of the helix and travels along the wire with the velocity of light. If the velocity of the electrons is adjusted to a critical value depending on the ratio of the pitch of the helix to its diameter, energy is transferred from the electron beam to the electromagnetic field in the spiral. Thus the signal is amplified and gains of 30 db. or more are possible. The characteristics of the tube are such that band-widths of several hundred megacycles per second can be obtained.

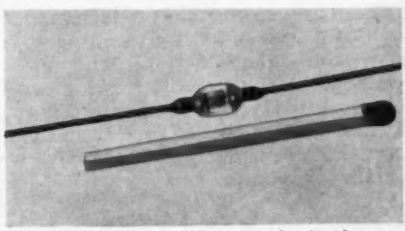


Fig. 35.—Germanium rectifier crystal. A safety match is shown alongside to indicate the size.

For the measurement of very small D.C. or low frequency currents, such as those produced in photocells and ionisation chambers, a new

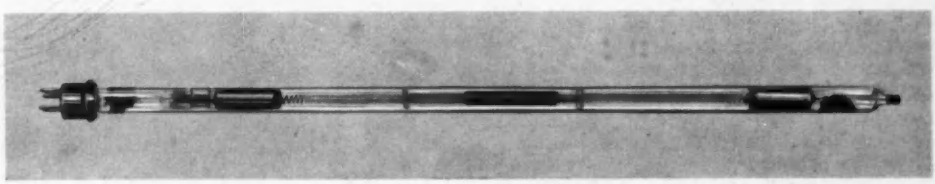


Fig. 33.—Travelling wave tube.

miniature electrometer triode (fig. 34) has been developed. This has approximately the characteristics of the E.T.1, but its small size, ruggedness and low filament current (25 mA.)

Fig. 36.—Projection cathode ray tube.

make it suitable for use in portable equipment, and its low capacitance results in increased sensitivity.

Considerable progress has been made with point-contact germanium rectifiers. The outstanding feature of these is their low forward and high reverse resistance. They will withstand peak reverse voltages of many tens of volts and thus are suitable in many applications where diodes have hitherto been used. The rectifier unit (fig. 35) is intended for direct soldering into the circuit, and its small size has resulted in a very low capacitance, of about 0.3 micromicrofarads.

The work on Geiger-Mueller counters has now resulted in small scale production of two types, GM 2 and GM 4, for counting β rays with velocities above 500 kV and 150 kV respectively. A further type is being evolved for still slower β rays. This incorporates a thin mica window and is filled to nearly atmospheric pressure in order to equalise the thrust on both sides of the mica.

Cathode Ray Tubes.

The considerable interest which is being shown in the production of large television pictures has led to the development of a projection cathode ray tube (fig. 36). It is designed for use with a Schmidt optical system giving a picture size of approximately 16 ins. by 12 ins.

In the construction of this tube new techniques have been employed in joining the optically worked end to the bulb, and in bringing out the high tension lead. As the operating voltage is 25 kV, special attention has had to be given to electrode insulation and to the avoidance of point discharges.

The chief problem in magnetically focused tubes is the prevention of damage to the screen by negative ions. This has been overcome by the use of an ion trap consisting of a number of coaxial cylinders suitably positioned on the axis of the focusing field. The electron beam passes to the screen while the negative ions of relatively high mass are deflected and collected by the cylinders.

Measuring Instruments.

Simple, rapid and accurate measurement of frequency is required in connection with the manufacture of multi-channel telephone equipment employing numbers of filters dependent upon the frequency characteristics of precisely adjusted crystal resonators. A measuring set has therefore been developed which provides a direct indication of frequency.

An equipment with a range from 10 c/s. to 10 Mc/s. is shown in fig. 37. The frequency to be measured is successively heterodyned with standard frequencies of descending values. In the first stage it is heterodyned with a known standard and the first figure of the value of the

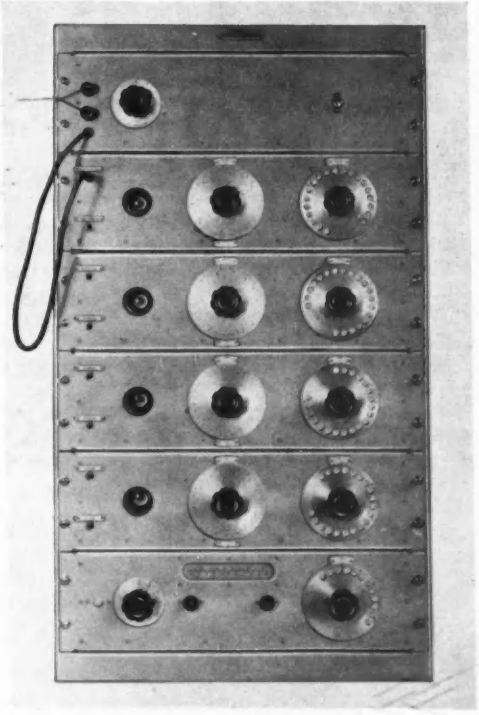


Fig. 37.—Frequency meter covering the range from 10 c/s. to 10 Mc/s.

frequency displayed automatically. The beat frequency from the first stage is again heterodyned, in the second stage, with a lower standard, and the second figure similarly displayed. This process is continued until the final stage is reached, in which a deflection type meter indicates the remaining figures to an accuracy of 1 c/s.

Radio impedance measurements can usually be carried out at frequencies below 20 Mc/s. and above 300 Mc/s., but there has hitherto been little demand for accurate measuring equipment for frequencies between 20 and 300 Mc/s. The recent rapid expansion of frequency modulated and amplitude modulated broadcast and communication in this range has, however, created an obvious need for accurate instruments.

An equipment using coaxial line techniques has been designed for determining such quantities as impedance and dielectric loss at frequencies above 45 Mc/s. An impedance measuring set has also been developed covering values from 1 to 100,000 ohms in a single range.

The use of radio frequency equipment for electro-medical purposes raises unusual measurement problems. In particular the physiotherapist needs to know the power actually entering a patient during short wave diathermy. The high frequency currents are carried from the generator to the patient's electrode by a cable, and although it is possible to measure the power entering the cable, the proportion entering the patient is unknown. An analysis of the transmission line equations shows that if the attenuation and length of the cable are suitably chosen a *fixed* proportion of the total power invariably reaches the patient. It is thus necessary to provide only a wattmeter to measure the total power.

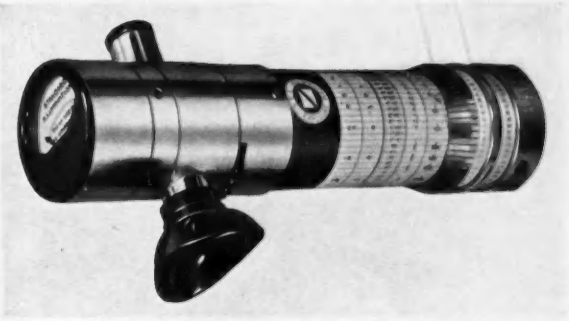


Fig. 39.—The exposure photometer.

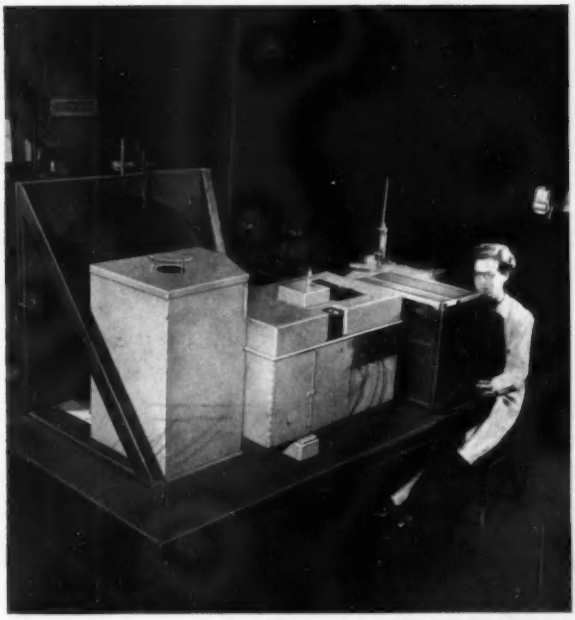


Fig. 38.—The photo-electric photometer in use in the Research Laboratories.

Another electro-medical requirement is accurately to measure small direct currents, such as the ionisation currents produced by radiations from atomic disintegrations. For this a very high resistance of about 10^{12} ohms, stable with time and temperature, is needed. A mixture of picric acid, toluene and absolute alcohol in the correct proportions will give stable resistors of values up to 10^{13} ohms, with a temperature coefficient of only 0.1 per cent per degree Centigrade. To obtain this reliability, the electrodes and the external surface of the glass tube which contains the resistive mixture must be prepared very carefully.

The apparatus in use in the Laboratories for studying light output, colour and colour rendering of fluorescent lamps has recently been improved by substituting for the E.T.1 electrometer triode originally used the experimental miniature valve described in Section "Radio and Valves." The smaller inter-electrode

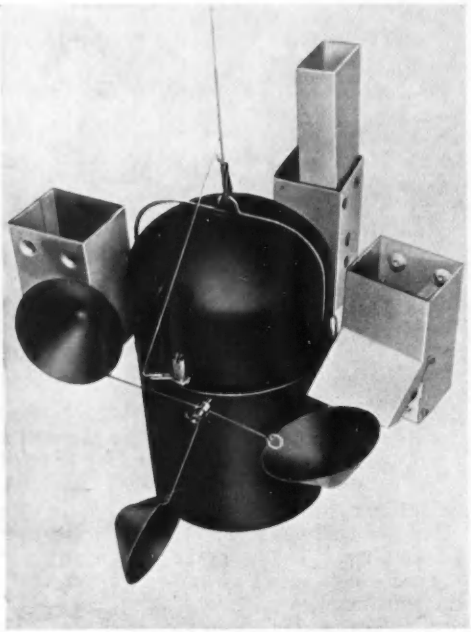


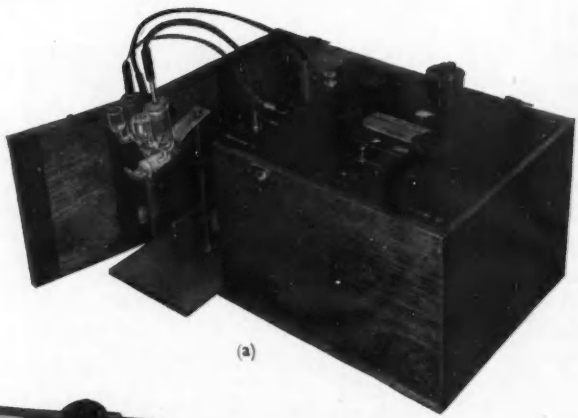
Fig. 40.—Radio Sonde equipment.

capacitance of the latter allows grid leaks of some ten times higher resistance to be used with a proportionate increase in sensitivity.

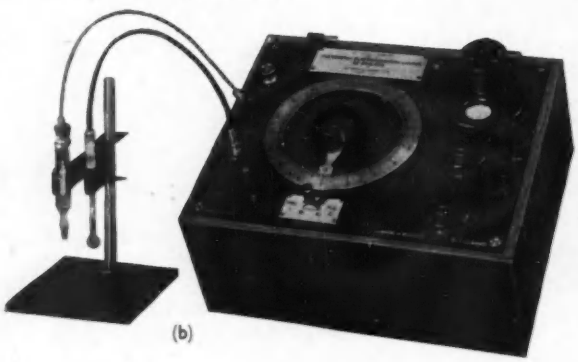
The complete apparatus is shown in fig. 38 with a 2 ft. 6 in. integrator. It is equally suitable for use with the 12 ft. diameter sphere recently installed to increase the accuracy of measurements on fluorescent lamps 5 ft. and longer. The apparatus can also be used to investigate the reflection properties of coloured surfaces or the transmission characteristics of light filters

An exposure photometer designed to measure the brightness of a distant object or a particular small area of a scene is now in commercial production (fig. 39). A telescopic optical system produces an inverted image of the object whose brightness is required, and this image is viewed through an eyepiece. In the centre of the optical field is a small comparison field illuminated by a lamp operated from a 1.6 volt cell contained in the instrument. The brightness is varied until it is the same as that of the image, when its value can be read off the instrument scale. Three scales give a total brightness range of 1,000,000 to 1, and direct readings of exposure time for photographic purposes in addition to general brightness measurements can be made. A self-contained calibrating circuit enables the instrument to fall within 10 per cent accuracy as stipulated for portable photometers to B.S.I. No. 230.

It is sometimes of great practical importance to establish the commercial production of an instrument previously made only in the laboratory. For example, the Radio Sonde technique has been used for studying upper atmosphere conditions for many years. Recently, interest in increasing the safety of air transport has focused attention on this method of investigating approaching weather. Radio Sonde equipment is now being manufactured to meet this demand (fig. 40). Electrical instruments measuring temperature, humidity and barometric pressure are carried into the stratosphere



(a)



(b)

Fig. 41.—(a) (above) Cabinet model pH meter. (b) (left) Bench type pH meter.

by a balloon. As the balloon rises, the readings of the instruments modulate a radio transmission from a miniature equipment within the apparatus. The radio signals are received and recorded at a ground station.

During many industrial processes frequent checks on quality are required. These can often be facilitated by using electrical measuring techniques. For example, an exact control of acidity or alkalinity, that is of pH value, is required throughout many chemical processes. Two pH meters have been developed to meet this need, one being a cabinet model and the other a smaller type for bench use (fig. 41 (a) and (b)). Each consists essentially of a sensitive and stable amplifier of high input resistance and an accurate potentiometer reading directly in pH values. Both are simple to operate and can be used with any form of electrode.

Such checks on quality are sometimes more useful if they are automatic. A typical example is the detection of unwanted iron particles in a material. The material is passed through the coils of the magnetic sorting bridge (fig. 42) described in a previous review. The presence of iron inclusions is immediately indicated by the bridge, and, by the addition of a trigger unit recently developed, can be caused to ring a bell, light a "reject" lamp," or even to stop the feed to the machine.

The Miniscope which, as mentioned in a previous review,* is a miniature oscilloscope, has proved so useful to radio servicing that a number of accessories have been produced for it. These include a unit incorporating an extra cathode ray tube which can be added to allow two related waveforms to be examined simultaneously.

* "Electrical Progress and Development," *G.E.C. Journal*, Vol. XIII, No. 3, February, 1945 p. 139.

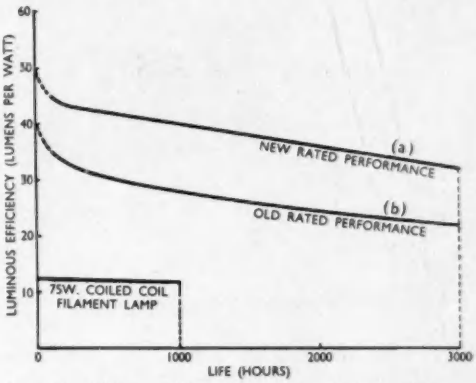


Fig. 43.—Efficiency/life relationship of Osram 80 watt fluorescent lamps.

The last item of equipment to which reference will be made is the magnetic tape recorder, which has been produced during the past year. It will record faithfully music or speech up to a frequency of about 6000 c/s. The recording is made on a plastic tape impregnated with a special magnetic powder, and has a maximum playing time of 35 minutes. The record is of such a size that it can be conveniently stored. Alternatively the programme can be "wiped" off, and the tape used again. The obvious uses to which the instrument can be put in business, in the home, in teaching and in rehearsal need no emphasis. It can also be used in industry to record any variable that is capable of being translated into electrical signals of audio frequency.

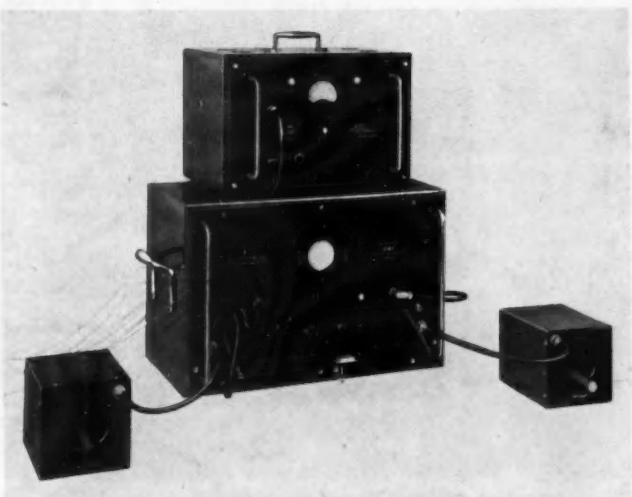


Fig. 42.—Magnetic sorting bridge and trigger unit.

DISCHARGE LAMPS AND THEIR APPLICATIONS.

Most of the year's work on the production of fluorescent lamps has been in the design and installation of large scale manufacturing machinery to meet the increased demand.

It is interesting that the Osram 40 watt 4 ft. fluorescent lamp introduced about two years ago has in no way affected the demand for the Osram 80 watt

5 ft. lamp. This latter remains by far the more popular of the two ratings in this country.

Mains voltage fluorescent lamps of greatly increased luminous performance have been

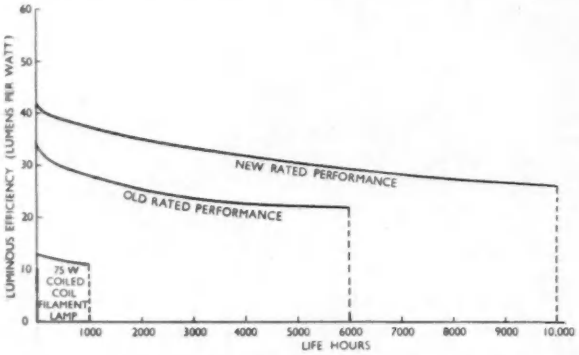


Fig. 44.—Efficiency/life relationship of Osram cold cathode fluorescent tubes.

introduced during the past year. They use the new halophosphate powders developed in the Research Laboratories. The curve in fig. 43 represents the performance of 80 watt Daylight fluorescent lamps based on old and new performance data. The curve for a 75 watt tungsten filament lamp is given for comparison. The areas under the curves are proportional to the lumen-hour output of each lamp. The average efficiency throughout life, namely 24 L/W and 38 L/W for the old and new lamps respectively, shows a gain of over 50 per cent. A similar improvement in warm white lamps has been achieved.

The new powders are also used in Osram cold cathode fluorescent tubes with a considerable gain in efficiency. This, coupled with their increased life, has brought these lamps to the forefront of modern light sources. Fig. 44 shows the relation between the old and new performances. Here again the curve for a 75 watt tungsten filament lamp has been included for comparison, and the areas under the curves are proportional to the lumen-hour output of each lamp.

Work has also continued steadily on other aspects of mains voltage lamps. Thus, for example, many trials are being made of new sizes and ratings. Some short low wattage lamps have been used for lighting coal mines and public transport vehicles.

Instantaneous starting has always been a feature of cold cathode lamps. Interest in quick-starting of mains voltage fluorescent lamps continues and satisfactory circuits have been evolved. It is not expected that they will supplant the widely used starter switch which has considerable merit on the score of cheapness and simplicity.

Dimming of cold cathode lamps was in use for several years before the war, and it is natural that similar demands should arise for hot cathode lamps. The problem here is that to ensure normal lamp life the hot cathodes must operate at a constant temperature over a wide range of lamp currents. No fundamental difficulty is involved, but the gear is necessarily more complicated than

Fig. 45.—The Royal Lounge in the train used in Their Majesties' tour of South Africa.

for steady operation. The use of hot cathode fluorescent lamps for flashing messages in morse code has been investigated and suitable circuits have been evolved. Some of the technical considerations are the same as those involved in dimming.

Difficult circuit problems also arise in the application of fluorescent lamps to train and 'bus lighting, due to the wide variations in voltage and frequency which are encountered. Reference has already been made in previous reviews* to the direct operation of fluorescent lamps on 600 volt D.C. supply in the Underground Railway and to the trial 1,200 cycle installation. In both cases special circuit problems had to be solved to ensure satisfactory lamp performance under all supply voltage conditions. Several thousand 2 ft. 20 watt lamps are now being installed in coaches under construction. They will operate from 850 cycle supplies.

The lighting of the royal train used during Their Majesties' tour of South Africa last year marks an important step in the application of the flouresecent lamp. Nearly 300 lighting fittings, together with their associated equipment, were designed and supplied. The fittings, which can be seen in fig. 45, incorporated Osram 20 watt 2 ft. lamps, and used frosted ribbed glass to diffuse the light.

Fig. 46 shows an installation of 15 watt Osram fluorescent lamps fitted in a public transport 'bus at Nottingham in collaboration with C.A.V. The lamps are operated from a 400 cycle, battery-driven generator. A resonance circuit is used which obviates the need for starting switches.

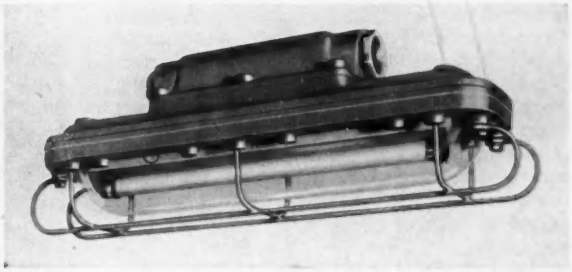


Fig. 47.—(a) (above) Flameproof mines lighting fitting for 18 inch fluorescent lamps. (b) (below) Flameproof coupler, 15-20 amps. capacity.

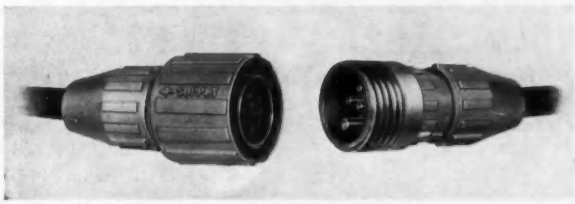


Fig. 46.—Interior of public transport 'bus at Nottingham equipped with fluorescent lamps.

New and interesting applications of fluorescent lamps have been mentioned from time to time in these reviews. Perhaps the most important innovation is the lighting of coal mines. A number of trial installations are being studied at the present time, using the flameproof fitting for an 18 inch fluorescent lamp. shown in fig. 47a. An installation in Chislet Colliery, Kent, is seen in the frontispiece on page 2 of this issue. A four-core screened cable is used, two being power cores, one the pilot and the other the earth core. An electrical interlock automatically cuts off the power if the cable is severed or if a coupler or lamp is disconnected. The coupler which is provided with five pins, so that it can also be

* "Electrical Progress and Development," *G.E.C. Journal*, Vol. XIV, No. 3, February, 1947, pp. 134-5.

used for drill couplers, is seen in fig. 47b. The earth core is continuous through the earth pin and sockets, thus eliminating the need for a "scraping" earth with its inherent danger.

The first fluorescent lamps for mine lighting were made in the G.E.C. Research Laboratories before the war. They were short cold cathode tubes operated from a transformer having an open circuit voltage to earth of 300 volts. Experiments carried out on these lamps by the Safety in Mines Research Board demonstrated for the first time the intrinsic safety of this type of discharge lamp in an explosive atmosphere.

Cold cathode fluorescent lighting has also been used for a very different type of application, namely, colour matching. The fluorescent coating is specially blended to reproduce the main spectral characteristics of the light from an average overcast north sky. Cold cathode lamps are used because of their excellent lumen and colour maintenance characteristics—a matter of great importance in a colour matching lamp.

An interesting application of Osram 80 watt 5 ft. fluorescent lamps to roundabout lighting is illustrated in fig. 48. The lamps are mounted in 25 single-lamp cut-off reflector lanterns which are attached to trolley-bus poles. The average illumination is 3 lumens per sq. ft., and complete freedom from glare is achieved.

Following the success of the fluorescent discharge lamp installation in the Brompton Road, London, work has continued on smaller fittings. Fig. 49 shows a unit equipped with lamps giving an "open" distribution. In spite of the severe weather of the winter of 1946-7 no serious difficulties in starting or running

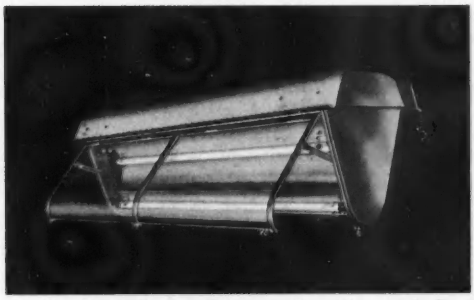


Fig. 49.—Street-lighting fitting for four 80 watt 5 ft. fluorescent lamps, with cover open.

the trial installation were encountered, and it appears that the major technical difficulties have been overcome.

A most interesting example of the many types of H.P.M.V. lamps on which work has been continued is the $2\frac{1}{2}$ kW compact source mercury-cadmium lamp. The improved colour rendering of this lamp makes it particularly suitable for film studio use. A number of problems has arisen in adapting it to these

Fig. 48.—An aerial view of Lansdown Roundabout, Bournemouth, lit by Osram 80 watt 5 ft. fluorescent lamps.

requirements. To mention but one, the lamp must be held ready for instant use between shots. This is achieved by mounting the lamp in the special housing shown in fig. 50, which is fitted with hinged reflectors, which can be moved by means of a lever to enclose the lamp completely, thus serving the dual purpose of keeping the lamp hot and cutting off the light. The lamp can then be maintained at its operating temperature by "simmering" at about 1 kW instead of the full 2½ kW, and is automatically switched to run at full brilliancy when the shutters are opened.

The design of the lamp itself ensures that it maintains the correct temperature distribution over its surface during use, and permits satisfactory operation when the lamp is tilted. The aluminium cone at the top of the lamp shown in fig. 51 prevents the top seal being overheated by radiation or convection from the hot quartz envelope. The disc at the lower end prevents undue cooling of the lower portion of the bulb by convection.

Experiments made in collaboration with the British Broadcasting Corporation at the Alexandra Palace Television studios have shown advantages of mercury-cadmium lamps. The radiant heating effect for a given illumination is much less than with incandescent lamps, and the set is, therefore, much cooler. The amount of near infra-red radiation is also relatively small: as a result the television camera gives better definition and better

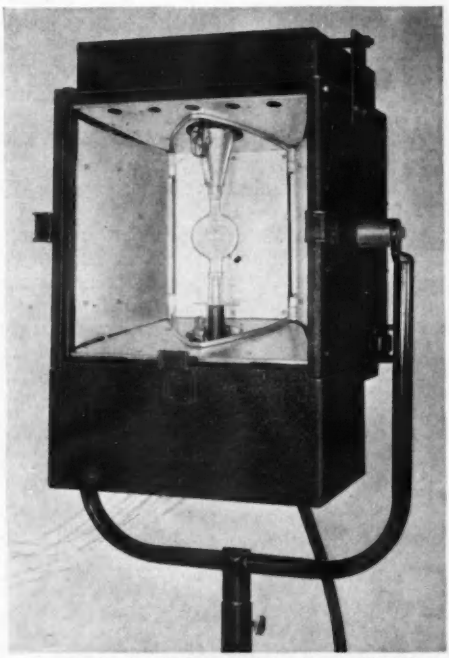


Fig. 50.—Studio floodlighting unit for Osram 2½ kW mercury-cadmium compact source lamp. The toughened glass front normally fitted has been removed.

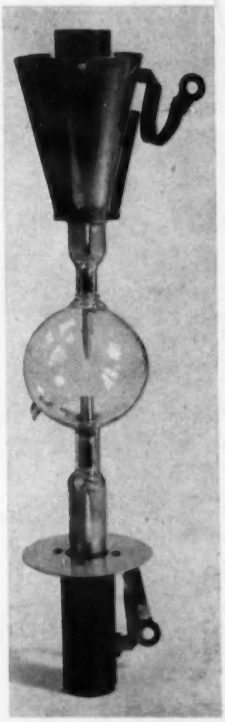


Fig. 51.—2½ kW mercury-cadmium compact source lamp for film studio work.

rendering of colour into monochrome. Much of the light on a television set must be provided by a large area source, to give soft shadows, and fig. 52 shows an experimental unit using a 2½ kW compact source lamp designed to replace a unit of the same light output having forty-eight 100 watt tungsten filament lamps. A band refractor and mirror system distributes light uniformly over a diffusing surface which acts as a secondary source.

Progress has been made in the methods of restarting compact source lamps in the high pressure condition. Several circuits producing pulses of various magnitudes have been designed, the pulse being generated by the rapid interruption of a D.C. current in an inductance.

To perform this function a robust vacuum switch has been developed which will, no

doubt, find applications in other fields. Briefly, it consists of two tungsten tipped electrodes sealed into an evacuated glass tube, one electrode being spring loaded. The switch is shown in fig. 53. The tube is mounted in a closely fitting solenoid, which when excited causes the contacts to close. Such a switch is capable of breaking D.C. currents up to 15 amps. with negligible arcing and with extreme rapidity, even though the voltage occurring at the break may be as high as 5,000 volts.

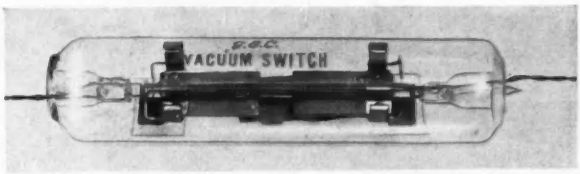


Fig. 53.—Inner vacuum tube for 15 amp. vacuum switch, showing contact assembly.

An experimental 5 kW compact source type free from stroboscopic flicker when operating on alternating current supplies is shown in fig. 54. The phases of a 3-phase supply are connected severally to the 3 electrodes through suitable ballasts. Arcs form between these electrodes, and as the total power dissipated at any instant in these arcs remains almost constant the light output from the lamp is similarly constant. The lamp may be choke stabilized; it therefore requires less power than a lamp operated on D.C. supply.

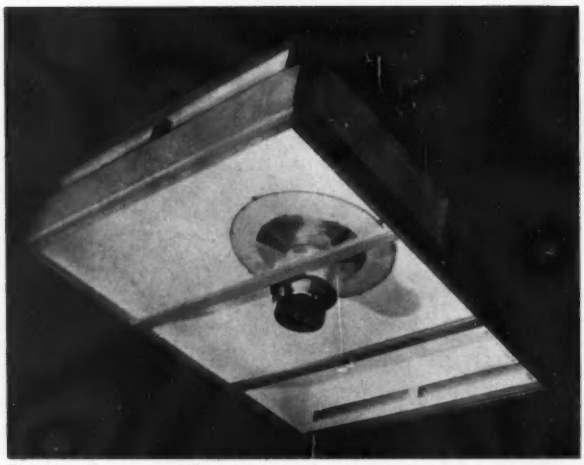


Fig. 52.—Experimental unit using 4½ kVV compact source lamp for lighting television studios.

The Osram 125 watt H.P.M.V. lamp still finds new applications. It has been used in the first two permanent installations of Uniway lighting opened in this country. The lanterns in this novel system direct light only towards the oncoming traffic in the tracks of a double-carriageway. This arrangement permits a very efficient fitting design so that only about one-third of the lamp lumens are required to give the lighting effect of normal two-way lanterns. Objects on the carriageway present a good silhouette contrast with the road surface, and to a driver on one road, the lanterns on the other road are apparently unlighted. Thus the confusion and glare arising from the multiplicity of light sources on a normally lit double-carriageway are avoided. Fig. 55 shows an installation of Uniway lanterns at Huddersfield.

Glass problems arise at almost every phase of electric discharge lamp development. Glass to withstand high temperature and the action of electrically excited mercury vapour is obviously required for high pressure electric discharge lamps. It is not so obvious that glass for fluorescent lamps, where the bulb temperature rarely exceeds 50 degs. C., must also resist mercury vapour attack. Any glass which blackens in the absence of the fluorescent material will give rise to rapid blackening of the fluorescent coating when used in fluorescent

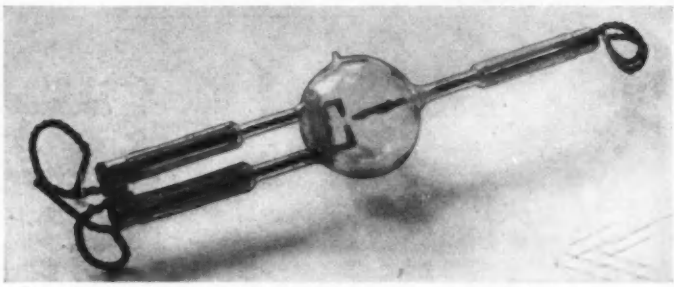


Fig. 54.—Experimental 5 kW compact source lamp for 3-phase operation.

lamps, with consequent light deterioration. Investigations at the Research Laboratories have shown that the surface condition of the glass rather than the bulk composition is all important; special glasses and glass treatments have been evolved which give substantial improvements in lumen maintenance.

The production of tubing of suitable quality for fluorescent lamps has involved studies of glass composition and also of the many technical problems which arise in meeting the close tolerances required in lamp manufacture. The main improvements in drawing tubing have resulted from the use of continuous melting tanks in which raw material, fed into one end of the furnace, flows out as refined glass to the tube drawing machine.

There is a wide variety of applications requiring discharge lamps of diverse types, and some of the more recent developments in this field are discussed below. A portable flash discharge equipment of really light weight and rapid recharging time is in an advanced state of development. It will be easy to operate and suitable for amateur or press photography. It is, of course, complementary to the studio

Fig. 55.—Osram 125 watt high pressure mercury vapour lamps in Uniway lanterns at Huddersfield.

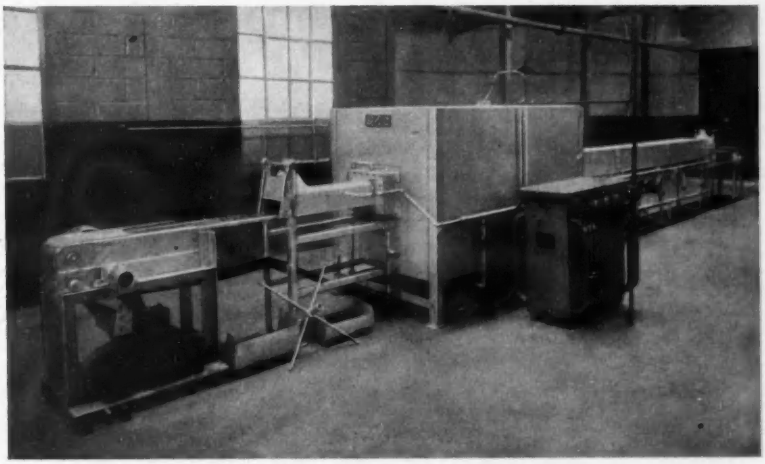


Fig. 56.—35 kW continuous brazing furnace.

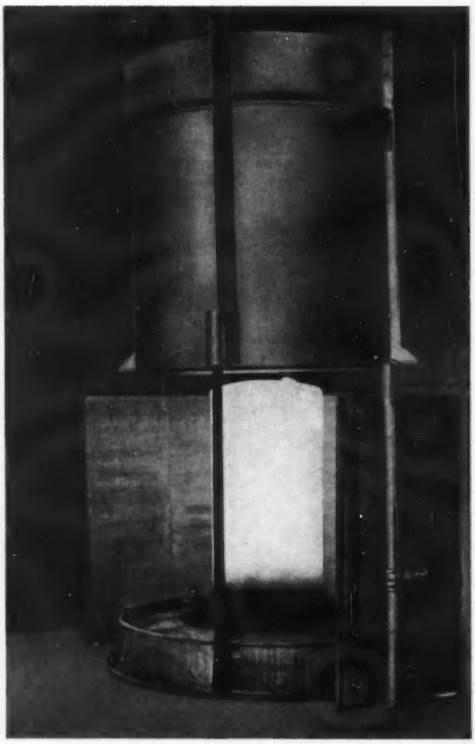


Fig. 57.—Gas malleableising furnace.

photographic flash equipment now in production.

Attempts to utilise the good colour and efficiency of similar discharge sources for normal lighting purposes by high frequency pulse operation have not been wholly successful owing to the disturbing stroboscopic flicker. Encouraging results have been obtained using normal A.C. and D.C. supplies with both rare and common gases.

Another flash discharge lamp of particular interest is employed in the "Photo-Finish" equipment used to eliminate human error in judging close finishes in horse-racing. The lamp takes the form of a narrow bore discharge tube of about 2 ft. light length which is placed immediately in front of the winning post and is set truly vertical. In operation the lamp gives accurately timed short duration flashes at the supply frequency of 50 cycles. These are recorded with a photograph of the horses as they pass the post by a continuously moving film camera mounted on the other side of the track. The flashes serve both as timing marks and as indication of true vertical on the photographic record.

A totally different type of discharge lamp is the new high intensity hydrogen arc lamp developed at the Research Laboratories. This provides a source of continuous ultra-violet radiation for use in absorption spectroscopy and has a crystal quartz window which transmits to about 1,800 A.U. The discharge is constricted by a narrow "gate" to give the high brightness required.

For sound film recording, an improved tube (type N.G.D.) has given good results in portable equipment and also meets the most exacting needs of high quality studio recording.

PROCESS HEATING.

Economy in the consumption of fuel and materials and a reduction in labour costs have been important aims in the design of new process heating equipment. Furnace brazing is an interesting example. It can frequently be used to enable complicated manufacturing methods, which necessitate the production of castings and several subsequent machining operations, to be replaced by a simple copper brazing process in which component parts are

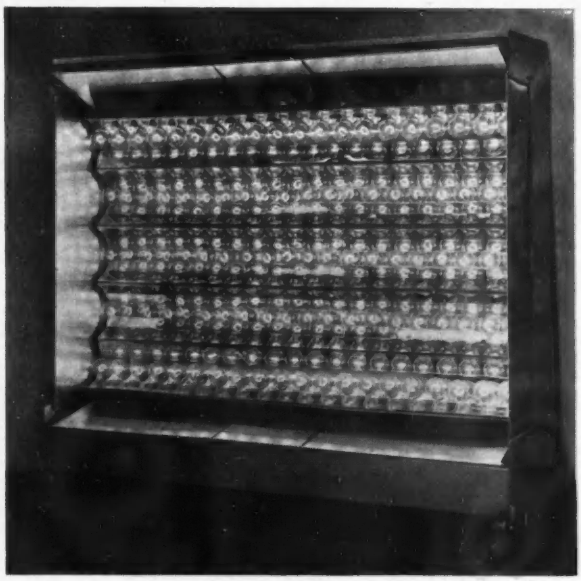


Fig. 58.—One section of the new trough type lamp plant for infra-red heating.

built up in a jig with intermediate layers of brazing material in the form of paste, wire or shims. After assembly, the jig is merely passed through a furnace and the joints are all brazed in a single operation.

Brazing temperatures are necessarily above 600 degs. C. For this reason the process is carried out in a controlled reducing atmosphere, which ensures that the product requires no subsequent pickling treatment and obviates the use of fluxes except where they are necessary to the formation of an alloy between the parent and the brazing metals. Although the minimum required temperature is 600 degs. C., the considerable progress in the manufacture of constructional materials for carrying heavy mechanical loads at high temperatures has allowed the use of equipments operating at temperatures over 1,100 degs. C.

Fig. 56 shows a 35 kW continuous furnace which is used in the assembly of accounting machine parts. It has a hot zone 5ft. long by 8 in. wide and 6 in. high, and the overall length including water-cooled zone is 35 ft.

Progress in gas-carburising and gas-malleableising has continued. In comparison with the old solid packing techniques, both processes give marked improvements by enabling the weight of extraneous material heated with the charge to be reduced, by saving time and by providing cleaner shop conditions. A typical gas malleableising installation is illustrated in fig. 57.

The use of electric heating for improving the methods of firing pottery is growing, and three rotary hearth decorating kilns have just been completed. They have a mean hearth diameter of 16 ft. 6 in. and are provided with continuously variable speed drives and automatic temperature controlling and recording equipment.

Lower temperature processes in the same industry have also been investigated and alternative types of radiant heating equipment, one using infra-red lamps and the other open coil elements, have been developed for the preliminary drying of wet clayware and for drying the glaze on biscuit-ware. By using continuous plants much of the hand labour in the old drying room methods has been avoided, and the marked reduction in drying time has enabled the plaster moulds to be returned for re-use

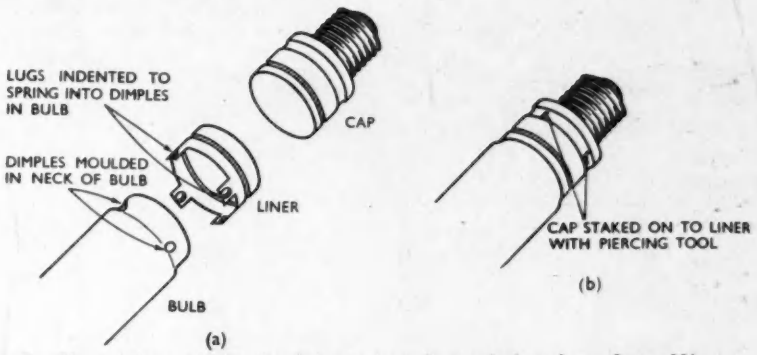


Fig. 59.—(a) Assembly details of the mechanically attached cap for an Osram 250 watt radiant heat lamp. (b) The cap slipped over the liner and fitting snugly on the neck.

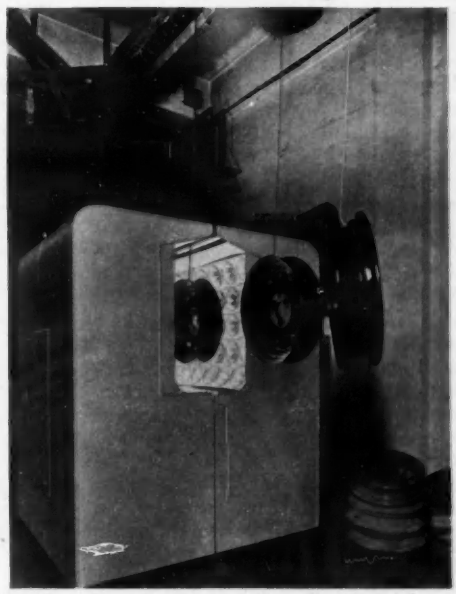


Fig. 60.—Infra-red oven using internally silvered lamps.

much more quickly than heretofore with a resultant reduction in the number of moulds necessary for keeping an article in continuous production. For instance a high intensity radiant oven for drying earthenware cups to the state where they can be withdrawn from the moulds for the attachment of handles. The drying process takes about six minutes.

Fig. 61.—Radiant oven for pre-heating plastic material.

The standard trough construction of lamp plant for industrial radiant heating has been improved by a redesign which gives a more enclosed structure and enables plants to be built up quickly, using standard pressed components, into any desired reflector contour (fig. 58).

Infra-red lamps with internal reflectors are now being manufactured by the Company. They have the same rating, 250 watts, as the clear pattern, but can be mounted at closer centres because of the simpler external reflectors, and can therefore provide faster rates of heating. To withstand high temperature conditions, the lamp cap is fitted mechanically to the bulb as shown in fig. 59 instead of being attached by the usual cement. This involves accurate moulding of the top of the lamp bulb to accept the preformed cap-shell. Although the primary reflectors are incorporated in the bulbs it is still important to mount these lamps in properly constructed plants with secondary reflectors to redirect stray radiation and prevent currents of air from circulating around the charge and cooling it. In the new range of standard reflector-lamp plants a sectional construction similar to that of the new trough plants has been used, the individual rows being hinged along their edges so that they can be set at any desired angle. A reflector-lamp plant for stoving the enamel on car wheels is shown in fig. 60.

Investigation of the pre-heating of pellets of thermo-setting plastic moulding materials suggested that there were many mouldings for which the high speed and uniformity obtainable with high frequency heating were not particularly necessary, but where there was much room for improvement over the old convection oven methods. To bridge the gap a special radiant oven has been developed (fig. 61). The

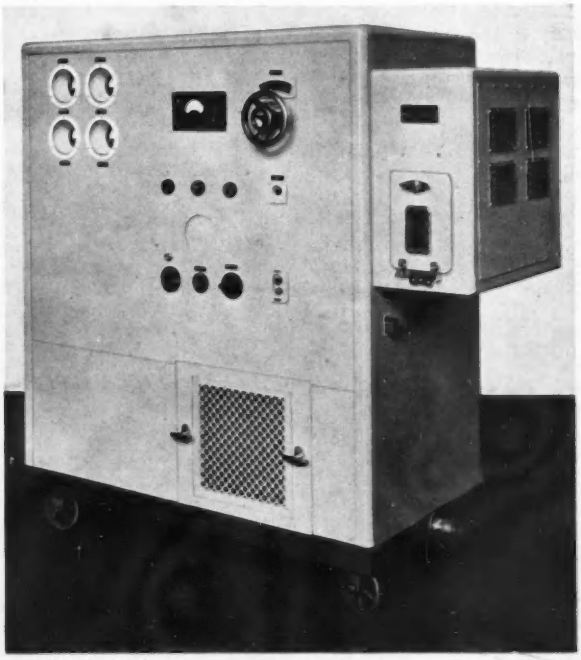


Fig. 62.—Radio frequency heating set showing new design of equipment for heating plastic powders.

charge of moulding material is placed on trays and is heated by radiation from two thermostatically controlled panel type heaters mounted at the top and bottom of the oven. It can be used with advantage for most mouldings of low and medium thickness and frequently permits reductions of the press cycle sufficient to increase the output of the press by 30 per cent. There are also advantages from reduced risks of insert pin breakage and of porosity in the mouldings.

Developments in high frequency heating have been directed towards improving the performance of the standard range of generators and work-handling equipment. With some of the earlier high frequency ovens for pre-heating powdered materials, where the electrode was pressed into contact with the upper surface of the charge, it was not always possible to obtain full repeatability and uniformity of heating. This applied particularly with powder and flake, where variations in packing density caused by the use of different electrode pressures on successive batches produced corresponding variations in voltage gradient and heating rate. Furthermore, with flake, the difficulty of ensuring satisfactory contact between the irregular surfaces and the horizontal electrodes resulted in variations in heating rate from point to point within the charge. These difficulties have been overcome in the new design by mounting the electrodes vertically at a fixed spacing, and by supporting the charge in a wooden container (fig. 62).

In many high frequency heating processes the electrical properties of the load vary during the course of the heating cycle. When a load which is initially matched to the generator

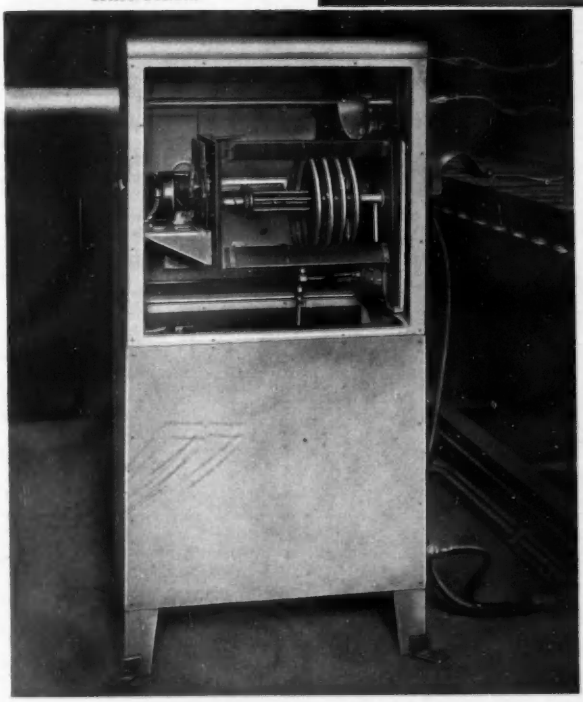


Fig. 63.—(a) (right) A 25 kW high frequency heating set in use for the setting of glue in the manufacture of plywood. The variable inductance matching unit is seen between the set and the press.
(b) (below) The matching unit with cover removed to show details of construction.

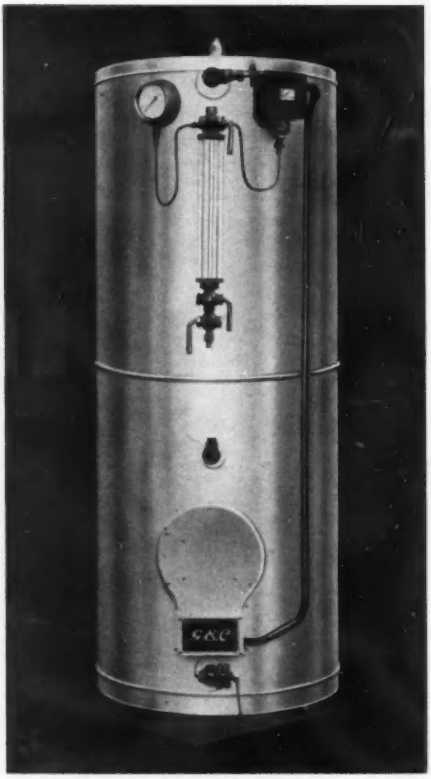


Fig. 64.—Storage type steam raiser.

becomes out of match, the generator operates at reduced efficiency. It may therefore be important to re-match during the cycle to compensate for load changes. The 25 kW set, seen in fig. 63 (a) and (b), in use for the manufacture of plywood, incorporates a variable inductance for this purpose. It is watercooled and has silver graphite contact brushes capable of carrying 100 amps. It is continuously variable over its entire range and can be operated without interruption of the heating cycle. The reversible motor drive is controlled manually by an unskilled operator who maintains the deflection of a single meter constant by operating a pair of push buttons.

Hitherto, control of eddy current and dielectric heating cycles has been obtained by including a process timer in the generator circuit. This is satisfactory so long as the circuit conditions remain unchanged, but if the input voltage varies, there will be corresponding variations in the energy supplied to the charge and in the heating cycle which it experiences. For processes where the heating cycle is critical a new controller has been developed to deliver a predetermined amount of energy independent of changes in the supply voltage. It is similar in appearance to the process timer but is calibrated in energy units instead of in minutes or seconds.

AGRICULTURAL AND DOMESTIC HEATING EQUIPMENT.

A new steam-raiser has been developed in which steam is stored under pressure in a lagged vessel (fig. 64). Thus, steam generation need no longer be confined only to those periods when actual steaming is taking place. In this equipment, a maximum of 80 lbs. of steam is stored at 90 lbs. per sq. in. pressure, control being effected by a pressure-operated switch, which interrupts the supply when the maximum pressure is reached.The loading of the steam raiser is only 3 kW, but it can supply steam for a limited but sufficient period at the same rate as a 20 kW non-storage type of equipment. This economy is important in rural installations in which, previously, the steam-raising load was a substantial item.

Once the supply of steam is exhausted, the storage steam raiser requires time to recover, but in normal dairy procedure the demand for steam is in any case intermittent. The 3 kW loading will be satisfactory for normal applications, but where speedier recovery is required and electrical supply conditions permit, the loading may be increased to 6 or 9 kW.

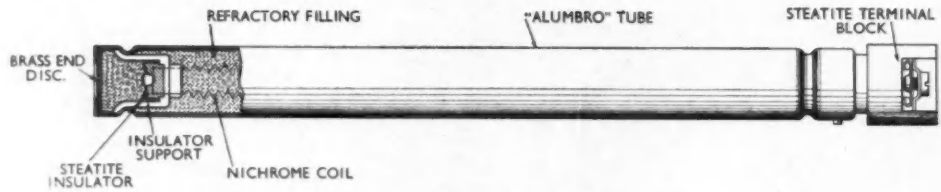


Fig. 65.—Details of the new water heating element.

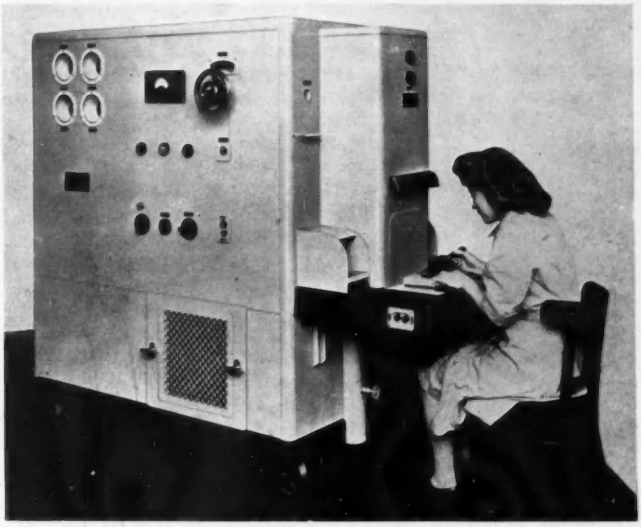


Fig. 66.—High frequency heating equipment in use for tool tipping.

For general water-heating purposes, a new immersion heater, which is lighter than the old cast pattern and easier to produce, has been developed. It is manufactured in much the same way as a sheathed wire element; the resistance coil, in the form of a loop, is supported inside an aluminium-bronze tube which is filled with a powdered refractory material. The tube is then drawn down to consolidate the insulation and hold the coil in position. The finished element is $\frac{3}{8}$ in. in diameter and is available in loadings of 500, 750, and 1,000 watts. Details of the construction of the element are shown in fig. 65.

The new cooker thermostat mentioned briefly in a previous review of progress* has now been in full production for some eighteen months. The confidence placed in the snap action switch mechanism developed for this thermostat has been amply justified and large numbers are now in use in cookers throughout the country. The temperature differential of the thermostat is held constant during 100,000 operations by maintaining the load on the two tensioned members of the leaf spring toggle system; this has been made possible by use of a special helical loading spring. The thermostat has also found applications for industrial temperature control purposes, as, for example in the radiant plastic preheating oven, mentioned above.

* "Electrical Progress and Development," *G.E.C. Journal*, Vol. XIV, No. 1, February, 1946, p. 48.

DEVELOPMENTS IN FACTORY EQUIPMENT.

The adaptation of new methods and principles for practical use in manufacturing has played an important part in improving the speed and efficiency of production. Some typical examples are described below.

Tool Brazing.

One of the purposes for which high frequency heating is particularly suitable is for brazing tungsten carbide tool tips on to the tool steel shank. This operation was first performed by means of a blowpipe, a method which suffers from a number of drawbacks. A 5 kW H.F. set arranged for brazing the tips is seen in fig. 66, the important part being a single-

Fig. 67.—A batch of 5 kW high frequency electronic heating sets approaching completion prior to despatch. These sets are for a variety of uses such as the dielectric heating of plastics, inductive heating for tool tipping, brazing, soldering and case hardening.

turn work coil in the form of a copper tube through which there is a continuous circulation of water.

The operator places the tip, brazing metal and flux in position and slides it into a slot under the coil. By means of a foot switch she then turns on the high frequency current and the tool and tip are quickly brought to brazing heat. The tip is then pressed into place with a probe, the tool is withdrawn and the work is finished. As well as being very rapid, this method is greatly superior to that in which a blowpipe is used both in cleanliness and in localisation of the applied heat.

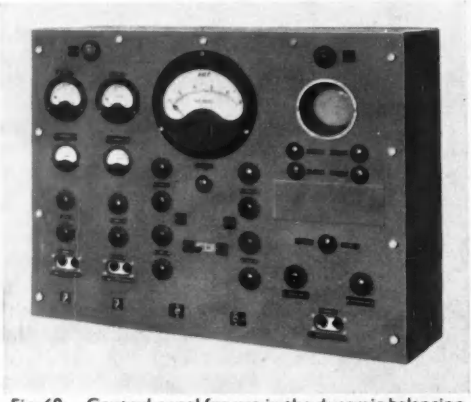


Fig. 68.—Control panel for use in the dynamic balancing of the rotors of turbo-alternators.

A batch of 5 kW high frequency electronic heating sets in course of assembly is seen in fig. 67.

Balancing the Rotors of Turbo-Alternators.

As most engineers are aware the balancing of large rotors for turbo-alternator sets has always been a laborious task. Following the success of the small electrical dynamic balancing machines built at Witton Works, a similar balancer for rotors up to 40 tons was designed, and is now in course of construction. The principle is retained of generating voltages proportional to the vibration at each bearing and of then mixing these voltages to obtain a direct record of the balance weights required. The method of showing the position of unbalance, however, is no longer stroboscopic, but makes use of a small alternator driven from the rotor. The output of this alternator is phased with the ultimate unbalance voltage by rotating its field system and using a cathode ray tube as the indicating medium. The position of the alternator field system shows the position of unbalance to within half a degree.

The larger balancer is handicapped by the fact that each rotor tested will be different from its predecessor, whereas with the smaller balancer a large number of similar rotors can be made and used for initial calibration. Therefore, for new rotors, it is necessary electrically to simulate perfect balance for calibration purposes. This is done by backing out the unbalance voltages of the vibration generators during the calibrating run so that, to the instruments, the rotor appears balanced.

With an entirely new type of rotor, a complete calibration, as well as the actual process of balancing, can be performed in a total of five runs of the rotor up to a speed of no more than 600 r.p.m. The time taken, exclusive of that required to fix the weights, should be about one hour as compared with the days previously needed. The accuracy should also be improved.

In fig. 68 can be seen the instrument panel and all the balancing controls for the large model balancer.

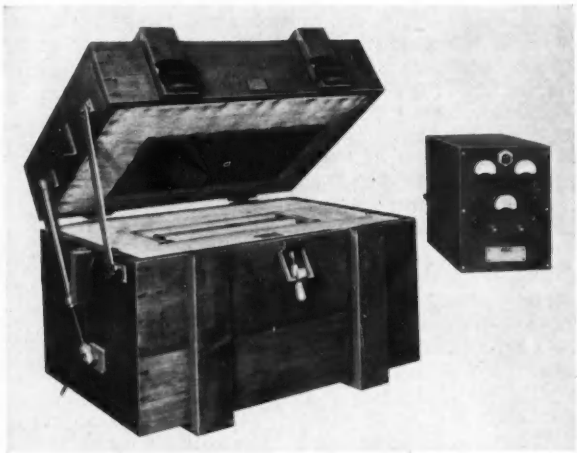


Fig. 69.—Apparatus for silence testing of fluorescent lighting chokes.

Choke Noise Tester.

Chokes for use with fluorescent lamps are carefully tested for silence before being despatched. As with much other static apparatus, a small amount of noise might

be produced which would pass quite unnoticed unless the choke were tested in a specially silent enclosure. For such purposes a silence chamber is available in which samples of various products can be tested. However, as it is necessary for routine tests to be made in the shops on every choke produced the testing enclosure shown in fig. 69 has been constructed by the Development Laboratory at Witton Works. As can be seen, it consists of a large box, every side of which, including the lid, is lined with a considerable thickness of sound attenuating material. This box contains a sensitive microphone and sound measuring equipment so that when a choke is enclosed within it a definite measurement can be made of any noise it produces. These tests make it possible to guarantee that chokes, tandem transformers, control gear and the like are really silent, even when used in such places as private houses or hospitals.

AUTOMATIC SENSITIVITY CONTROL FOR A CONTINUOUSLY EVACUATED CATHODE RAY OSCILLOGRAPH.

A system has been devised for maintaining constant operating conditions when recording impulse phenomena with the continuously evacuated cathode ray oscillograph. This condition is achieved by leaking carbon dioxide gas into the electron gun chamber. The quantity admitted is made a function of the heat supplied to a phial of calcium carbonate which depends upon the discharge tube current. In this way the necessary correcting influence is established when a change occurs in the current flowing in the gun.

FOUNDRY BOX KNOCK-OUT.

The foundry box knock-out is one of the latest applications of Sherwen electro-magnetically operated equipment (fig. 70). The vibrator is supplied directly from the A.C. mains through a half-wave metal rectifier; thus on a 50 cycle supply the speed is 3,000 cycles per minute. The movement is vertical, and the amplitude is controlled by a rheostat. Renewable and reversible grids are fitted to the table frame with a 2-inch square aperture heavy mesh below for screening out the sand. The undercarriage is of cast iron and the machine rests on rubber shock absorbers so that special foundations are unnecessary. The average power consumption of the knock-out installed at Witton Works is only ½ h.p., although 2 h.p. are required when operating at full intensity. The installation has proved very successful, maintenance has been nil, and two further machines have been ordered.

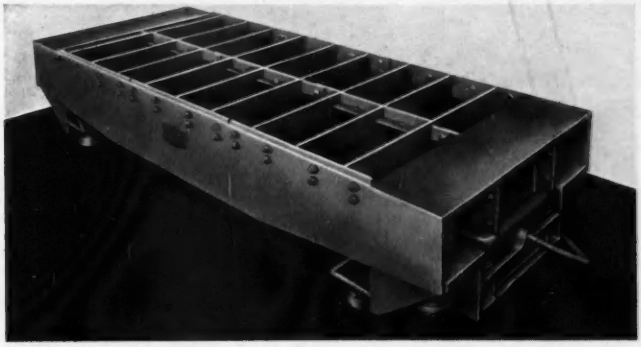


Fig. 70.—Electro-magnetically operated Sherwen foundry box knock-out, 9 ft. by 6 ft.

It may be added that this new development has created a good deal of interest amongst foundry engineers, to the extent that orders have been received for knock-outs capable of handling boxes up to 12 tons.

Ground Lighting for Civil Flying

By H. J. TURNER, B.Sc., F.I.E.S.,
G.E.C. Research Laboratories.

INTRODUCTION

THE purpose of aerodrome ground lighting is to give visual signals which, together with radio aids, will enable a pilot to take-off or land his aircraft by day or night. The lighting aids discussed here relate particularly to civil flying. There is at present much confusion between civil and military requirements. During the war a great deal was learned about ground lighting, particularly from bomber operations, but the landing aids provided were designed for that special purpose and also to cater for aircraft which, to use the slang of that time, had been "shot up."

Aircraft arriving at a civil airport converge on a central area after touch-down, and those departing leave from the same area. In bomber operations the aircraft were dispersed immediately on landing. This means that both air and ground control arrangements are different, and this in turn necessitates differences in lighting aids, particularly in respect of their layout on the ground.

The international character of civil flying makes it important that some degree of standardisation in aerodrome lighting shall be agreed as soon as possible. Efforts in this direction are being made by the International Civil Aviation Organisation (I.C.A.O.), but it is difficult to make progress internationally until the various national bodies have determined what is best for themselves. It cannot be said that any such agreement has yet been reached in this country, but the British Standards Institution has made a material contribution by codifying what is best in present day practice in the form of a Guide.*

The coloured diagram at the end of this article is a typical airport plan with a full lighting layout arranged in accordance with the recommendations of the B.S.I. Guide.

AERODROME LIGHT BEACONS.

The function of an aerodrome light or location beacon is to indicate the position of an aerodrome. Such beacons are flashing in character and the B.S.I. Guide recommends that they should be visible at a distance of at least 25 miles. For this purpose a beam intensity of between 2 and 3 million candles is suggested, the beam elevation being adjustable between 1 and 3 degrees above the horizontal.

* British Standard 1332: 1946. Guide to Civil Land Aerodrome Lighting.

Radio aids at present available combined with the navigational skill of the crew should enable an aircraft to be brought within 25 miles of its objective. While no aid that may contribute to safety should be neglected, such "long distance" visual aids will fail in conditions of mist or low cloud so that pilots must in any case be prepared to rely on non-visual aids for navigation. Furthermore, it would seem that if high intensity beacons are used at any considerable number of aerodromes in a densely populated area such as south-east England the results are liable to be confusing.

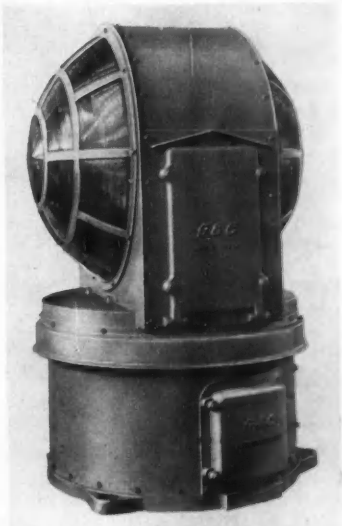


Fig. 1.—Two-flash aerodrome light beacon.

However, in a continental desert area it is likely that a beacon would be of value.

Fig. 1 shows a new type of rotating two-flash beacon which has recently been designed. It consists of a housing carrying the optical system, mounted on rollers running on a machined track. This is totally enclosed in the base which also contains the motor and gearing and an automatic lamp changing mechanism.

The optical system comprises two identical prismatic lenses each built up in sections as part of a sphere. A 1,500 watt projection lamp is used with its filament situated at the common focus of the two lenses. A colour screen can be

fitted so that the beacon signal may consist of alternate white and coloured flashes. The colours recommended are green for land aerodromes and yellow for seadromes. The beacon rotates at 10 r.p.m. giving a flash every 3 seconds.

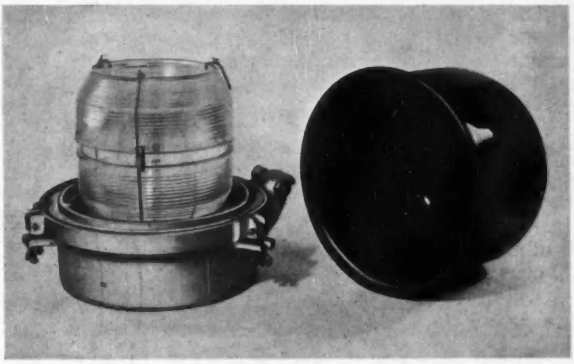


Fig. 2.—Low intensity approach light fitting showing refractor assembly with red glass removed.

Future developments in beacon design lie largely in the field of new light sources. Electric discharge lamps are now being developed which can be flashed for short periods at a high brightness and it is possible that a very high intensity will be obtainable from such a lamp without employing an optical system as large as that now necessary. It remains to be discovered how short flash times, of the order of a few microseconds, affect the visibility range and how good an indication of position will be given to an approaching pilot. It is often difficult to obtain an exact indication of position from a flash of very short duration.

APPROACHWAY LIGHTING.

This is one of the most controversial subjects in the whole field of aviation lighting. Approach lighting as distinct from runway or landing area lighting first came into extensive use during the war. Returning aircraft flew circuits round the airfield marked by a ring of "outer circle lights." Leading in at various points were strings of "lead in lights" which in turn led to "funnel lights" by means of which the pilot aligned his aircraft for the final approach and touch down. For bomber operations the flying of circuits was usually essential for many reasons, but the best practice for civil flying has not yet been established. It is agreed that the provision of outer circle lights is not necessary, but a decision as to whether circuits shall or shall not be flown affects the issue as to whether approach light fittings shall be visible through 360° in azimuth (omnidirectional) or whether their light output shall be restricted to a limited zone covering the normal direction of approach.

For flying in relatively clear weather the B.S.I. Guide recommends an omnidirectional approach light having a maximum intensity of about 900 candles of white light. A fitting now in production is shown in fig. 2. It consists of two prismatic refractors, circular in section, with a 250 watt projector lamp mounted inside so that the peak intensity is directed 5° above the horizontal. The lamp is mounted on a circular base casting adapted for pole-top mounting. Hinged to this is a cast ring carrying the refractors and a red glass dome which acts as a filter and as a weatherproof cover.

For conditions of low visibility, approach lights must have a high intensity. Further, it is important that the angles of light emission be restricted to the normal directions of approach

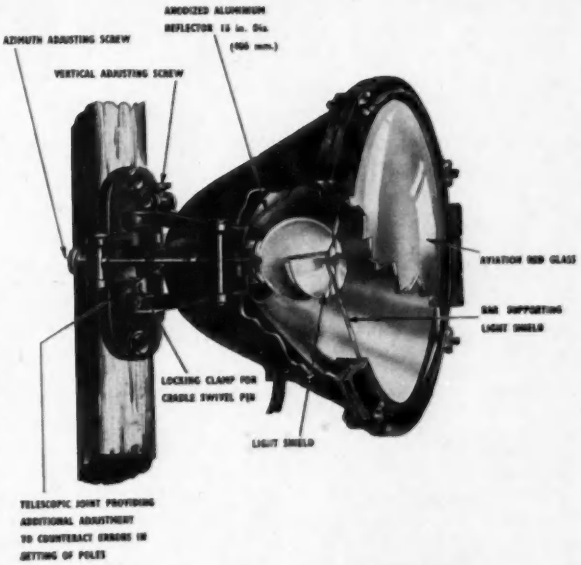


Fig. 3.—High intensity approach light fitting.

to reduce the background "haze" caused by light scattered in the fog and so that the wattage required may be kept as low as possible. This last is important since approach fittings may be sited up to 3,000 yards from the end of the runway. The unit shown in fig. 3 has a 250 or 500 watt projector lamp with a reflector designed to give a beam divergence of about 15° of maximum intensity about 100,000 candles, measured without the red filter.

The colour to be used for approach lighting is still being discussed internationally. Two or three years ago the favoured colour was red, but this puts a severe limit on the candlepower obtainable. The filament lamp is at present the only suitable light source and the use of a red glass filter causes the loss of at least 80 per cent of the light.

Of even greater importance than the design of fittings is the layout of approach lighting. Present practice is to use two lines of fittings of high or low intensity type, or both, on a fully equipped aerodrome. These lines may be up to 3,000 yards long and diverge from the end of the runway at an angle of 4°. The spacing between lights is about 300 feet. To get some idea of the pilot's view of this arrangement it should be drawn in perspective, not in plan, and such a view is shown in fig. 4. With this form of diagram it is possible to show that between the cut-off due to the cockpit of the aircraft and the blanketing effect of fog on distant fittings, the view of the two lines of lights is so restricted that the pilot does not see the desired "picture" of the approach path.

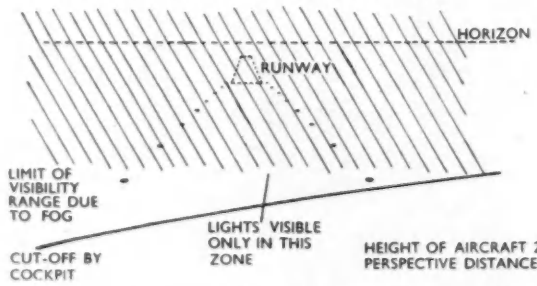


Fig. 4.—Perspective view from aircraft. This diagram was drawn by means of a perspective plotting web prepared at the Royal Aircraft Establishment, Farnborough.

It appears then that mere length in a lighted approach lane does not provide a solution. An approach system should indicate more than direction. It should indicate whether the machine is on the correct glide path, the distance travelled along the approachway and whether it is wing down on either side. A considerable study of these aspects of approach lighting has been made and full scale experiments are being conducted in America and in this country.

Any approach lighting system which is territorially extensive requires a large power supply network and its associated remote control and failure warning equipment. Also

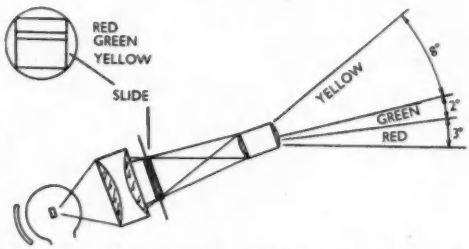


Fig. 5.—Optical arrangement of angle of approach fitting.

it is necessary to acquire wayleaves on a considerable amount of land. For this reason, consideration is being given to the devising of approach lighting aids which do not extend far beyond the aerodrome perimeter. Such aids would be of great value where the approach path lies across a city or over a stretch of water.

ANGLE OF APPROACH LIGHTS.

The function of these is to indicate the correct angle of descent in the later stages of approach. Two fittings are used for each approach lane, sited on either side of the runway about 150 yards from the beginning, so as to be opposite the normal touchdown point. The optical system used is similar to that of a lantern slide projector, the "slide" being formed of three colour filters as shown in the diagram of fig. 5.

The central (green) filter is ground accurately to such a size that the vertical divergence of the green part of the resultant tricoloured beam projected is exactly 2°. Provision is made for vertical adjustment of the beam as a whole so that the green section covers the glide path. In use, therefore, the pilot sees a green light when the aircraft is within 1° vertically of the correct glide path, a yellow light if he is high and a red light if he is low. A more accurate indication than $\pm 1°$ can be obtained, if desired, by adjusting the two fittings so that the glide angle coincides with the lower edge of one green beam and the upper edge of the other. The

correct angle is, therefore, indicated by green-red on one side, and yellow-green on the other. "Loss" of the green on either side means that the aircraft has deviated vertically from the correct glide path.

It is recommended that the light be occulting in character (normally by means of a revolving sector disc in front of the lens) with intensities of 800 candles for the yellow and 300 candles for the red and green beams.

THRESHOLD LIGHTS.

Threshold lights indicate the beginning and end of the paved runway. They may be arranged in the form of a bar across the runway itself, or so as to form a gate. In the first instance the fittings would be spaced at about 25 foot intervals; in the second, they would be spaced at 5 foot intervals in two 25 foot long lines on either side of, and at right angles to, the runway. It is recommended that green lights should be used at the beginning and red at the end of the runway. Fittings set into the paved surface will be subject to the same mechanical limitations as the contact lights which are described in the next section. In other words, they will be of the same size and construction and it follows that the use of green and red filters will reduce their intensity considerably below that of the contact lights. In foggy weather it is important that these lights should be visible at the same range as the contact lights. With the "gate" arrangement the fittings are sited off the paved area and may be designed differently so that their "green" intensity is equivalent to the "white" intensity of the contact lights.

It has been recommended that two sets of threshold lights should be used at each end of runways, one set to show green outwards and the other set to show red inwards. These are to be separately controlled and the appropriate pair switched on according to which landing direction is in use. The basis of this argument is that if a single set of fittings were used having red filters on the runway side and green filters on the approach side, a pilot approaching the runway from the wrong end would still see a green signal. The implication is that a pilot, in spite of radio aids and a lighted approachway, might make a compass course error of 180° and be confirmed in it by seeing the threshold lights.

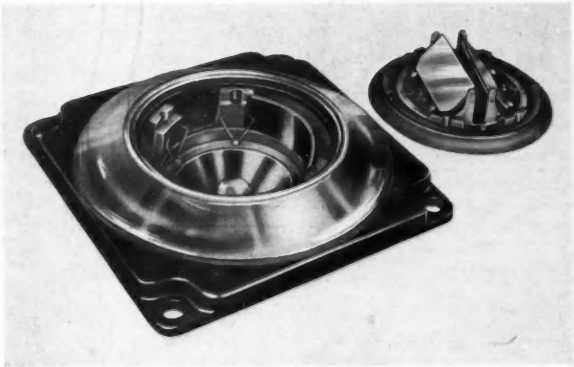


Fig. 6.—High intensity contact light fitting with top cover removed.

CONTACT LIGHTS.

The primary purposes of contact lights are to enable the pilot to :—

Complete the last stage of the approach.
Cross the end of the runway.
Make the actual touch-down.
Taxi so as to turn off the runway.

The accepted practice in this country is given in the B.S.I. Guide and is that the fittings be set in the paved surface, the maximum projection allowed being 2.5 inches. They are arranged in two lines, spaced 150 feet apart, the distance between fittings in each line being between 40 and 120 feet.

In America it is common practice to use much larger fittings standing 2 or 3 feet above the ground and placed just off the edge of the paving. These have the advantage of enabling intensities up to 200,000 candles to be obtained but may damage aircraft which run off the runway. Also the spacing between the lines of lights will vary according to the width of the runway and continuity is lost at runway intersections.

The height limitation of 2.5 inches carries a requirement that the contour of the fitting be smooth so that it will not damage the tyre of an aircraft. Fig. 6 shows a high intensity contact light now in production. It consists of a base casting carrying the main optical components: a spun aluminium paraboloid with a 6 volt 36 watt axial filament headlamp. This gives a vertical beam which is intercepted by two reflectors attached to the top cast iron cover, so producing two beams which are directed up and down the runway. The top reflectors are so arranged that the angles of elevation and azimuth of the two beams are adjustable. The top casting is seated on four lugs upstanding from the main casting which, therefore, takes the weight should an aircraft or vehicle pass over the

fitting. The aperture between the top and bottom castings is closed by a glass ring. This is seated on a rubber gasket in a machined groove in the lower casting and is also cemented with a bitumen based compound. A rubber gasket is cemented to the upper edge of the glass ring so that when the top casting is bolted down the gasket is compressed and the whole fitting rendered watertight. Air Ministry Specifications require that fittings of this type shall be immersed in water with an internal air pressure of 5 lbs. per square inch and that no air bubbles shall appear. The fitting must also be subjected to an evenly spread load of 16 tons without mechanical failure and remain watertight.

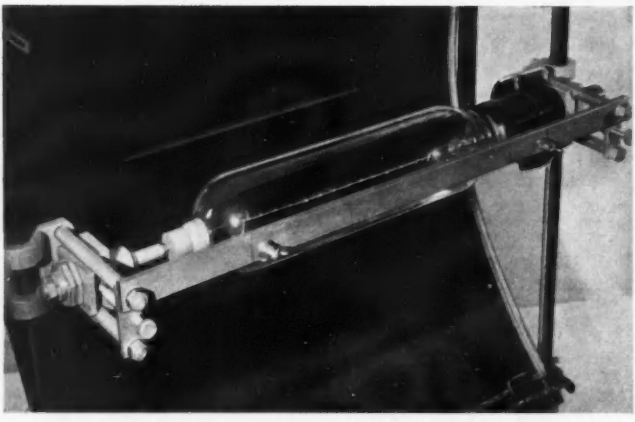


Fig. 7.—Mounting for horizon filament floodlight lamp.

Runway fittings are normally wired on series circuits from a regulating transformer which is wound so as to allow for a reasonable number of lamp failures without overvolting the rest. This also enables the lamps to be dimmed in steps to suit weather conditions. Protection of individual fittings is obtained either by using film cut-outs housed in the lamp caps or by means of isolating transformers. The latter method although more costly is to be preferred. Under the physical limitations imposed by the use of flush mounted fittings it is possible to get an intensity of 5,000-10,000 candles over a small angular range covering the normal direction of approach. At this intensity the lights will be visible in quite thick fog from an aircraft coming down the glide path but not in the course of making a circuit.

In fairly clear weather conditions it may be the practice to make a circuit and it has been argued that contact lights should show some light in all angles of azimuth in order to assist this circuiting. In very clear conditions this argument is reasonable since the required intensities are so low that a fitting with an all round intensity of about 10 candles would be quite adequate.

In less clear conditions, for example, when the state of the atmosphere is such that the meteorological daylight visual range is 3,000 yards, *i.e.*, "moderate visibility," an intensity of 10 candles would still enable a pilot to see the near fittings on the runway. But in circling the aerodrome at a distance of 2 miles an intensity of nearly 300 candles would be needed for him to see the runway lights. The argument, therefore, leads to a practical requirement which is absurd, *i.e.*, that a fitting whose purpose is to assist an aircraft about to land must have its maximum intensity at right angles to the runway.

The solution appears to lie in confining the light distribution from contact or runway lights to their primary purpose. If circuits are to be flown, the runway viewed from the distance of the circling aircraft could be delineated by about 6 additional lights on each side—*designed for that special purpose*. This was in fact the

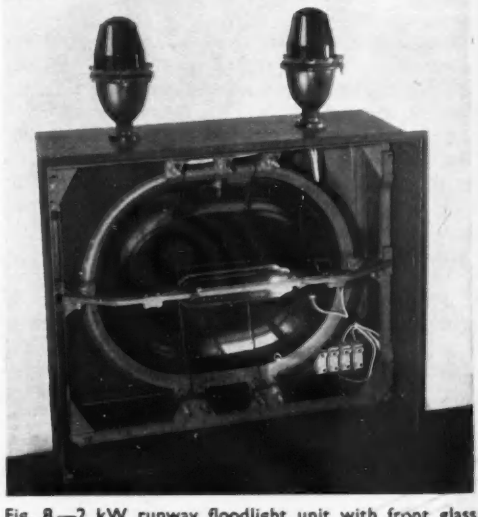


Fig. 8.—2 kW runway floodlight unit with front glass removed and also the louvre which cuts off upward light from the lamp.

AIRFIELD LIGHTING LAYOUT FOR MAJOR AIRPORT

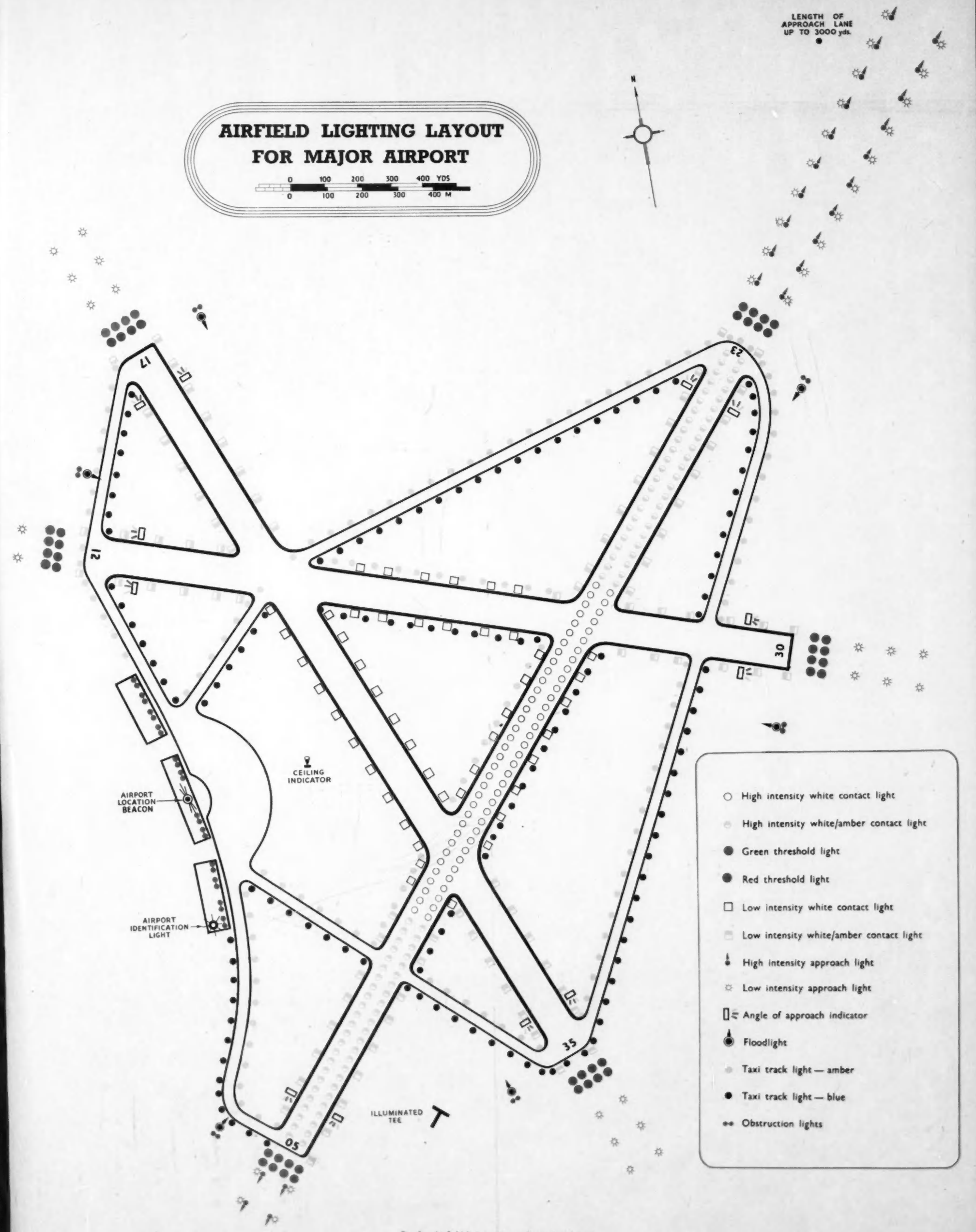


Fig. 9.—Airfield lighting layout for major airport.

function of the "circle" lights used on bomber stations during the war. The additional lights need not be on the runway itself; they could quite safely be placed, say, 50 yards to each side and would, therefore, not be subject to the physical limitations of runway lights. Fittings employing the same optical system as the low intensity approach light described in a previous section, could be used but emitting light through an angle of 180° in azimuth or probably a little less, so that they would not be visible from the approach lane.

RUNWAY AND LANDING AREA FLOODLIGHTS.

Landing area floodlights were extensively used before the increased weight and speed of aircraft necessitated the use of paved runways. Floodlights made up of several parabolic trough reflectors with line filament ("horizon") lamps were introduced by the G.E.C., and this type of optical system has so far not been bettered. The demand by the R.A.F. for mobile floodlights stimulated developments which resulted in the production of reflectors with extremely accurate parabolic contours and in methods of prefocusing lamps. Early models of the mobile floodlight were not equipped with prefocused lamps and this, combined with the lack of information given to maintenance personnel as to the best methods of training the beam, may account for a great deal of prejudice against landing floodlights. Many pilots never landed with the aid of a floodlight that had been properly set up.

The method of prefocusing and lamp support is shown in fig. 7. The 2 kW high efficiency horizon lamp is fitted with a dummy cap at the crown end. The face of the dummy cap and also the centre contact of the prefocus cap are drilled with coned holes each located on the line of the filament axis. The lamp is supported on a pair of coned points (as between centres on a lathe), one of them spring loaded and carrying the current. Provision is also made at this end for a current connection to the outer shell of the cap. The coned points are set accurately on the focal line of the reflector and thus, when the lamps are replaced, the necessary high precision of filament location is maintained.

A development of the simple cylindro-parabolic optical system for a narrower beam, runway floodlight is shown in fig. 8. Here the trough reflector is of such a width that the filament overlaps it by a half-inch on either side where a pair of half paraboloidal reflectors are mounted so that their foci lie on the focal line of the centre trough. The result is a high intensity (2 million candles) over a zone of about 5° in the forward direction. This arises from a full flash of the centre trough and a partial flash of the side reflectors. Outside this zone the intensity falls rapidly since only the centre trough is contributing. Some sideways spread is desirable because the floodlight should be mounted about 500 feet to the left of the runway so that the shadow of the approaching aircraft is thrown away to the right as it touches down.

OTHER GROUND LIGHTS.

There are some other items which can only be mentioned briefly. Obstruction lights are essential and taxi track lights are necessary at most large aerodromes. On small aerodromes, boundary lights mark the perimeter and luminous wind or landing direction indicators show the direction of approach.

The new equipment described is the outcome of recent work on aerodrome lighting in general. Several new methods of investigation have been devised and will facilitate further developments.

Under "Approachway Lighting" it was emphasised that approachway layout must be studied in perspective and some ingenious new perspective plotting webs are being used making it possible to draw quickly any ground view seen from an aircraft and on the diagram the outline of the windshield may be superimposed. Both here and in America dynamic laboratory scale models have been built by means of which the lighting engineer can approach and land an "aircraft" on any chosen pattern of ground lights. Outdoor proving grounds have been established where new types of equipment can be installed. The effects can then be observed in any weather conditions from towers or captive balloons. Actual flight trials are placed last in this list of experimental methods. They are important but have the major disadvantage that it is not possible either to choose the weather condition required or to make enough flights to cover all conditions. It is seldom possible to choose the best type of aircraft and usually the only observer who gets a good view is he who is lucky enough to get a seat beside the pilot. Flight trials, therefore, are best used in checking the results of laboratory and proving ground tests made under controlled or chosen conditions. Experience in service will, of course, give the final answer; new equipment is then used by the men who fly regularly and it is right that they should have the last word.

Stresses in Turbine Wheels with "Critical Taper."

By J. M. MITCHELL, B.Sc., G.I.Mech.E.,
Turbine Engineering Dept., Fraser & Chalmers Engineering Works.

THE stresses in a rotating turbine wheel may be found by the well known equations of A. Stodola. If the main profile is of hyperbolic form a difficulty sometimes occurs when the thickness varies rapidly with the radius, as in heavily loaded low pressure wheels and velocity stage wheels. To make this clear and to show how it may be overcome Stodola's theory will first be outlined.

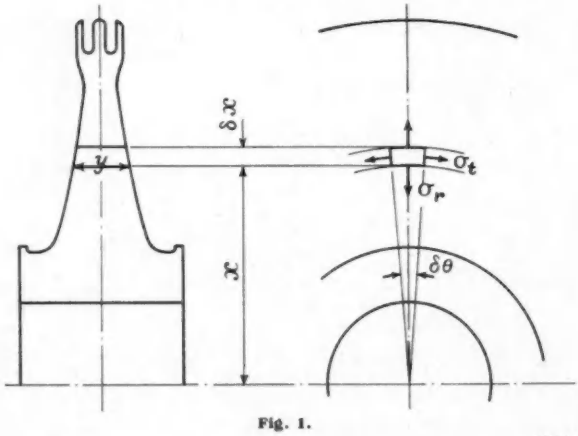


Fig. 1.

Referring to fig. 1, the following notation will be employed, as in Stodola's "Steam and Gas Turbines."

x in. = radius of point on hyperbolic profile of disc.
y in. = thickness of profile at radius x.
ξ in. = radial elastic extension at x.
σ_r lb/sq in. = radial tensile stress at x.
σ_t lb/sq in. = tangential or hoop tensile stress at x.
E lb/sq in. = Young's Modulus.
ν = Poisson's ratio.
$\mu = \frac{\rho}{g}$ = dynamic density of disc material.
ω rad/sec = angular velocity of disc.

If the profile is of hyperbolic form, $y = Cx^{-\alpha}$ where C, α are constants.

Then by fundamental laws of elasticity

$$\text{Hoop strain} = \frac{\xi}{x} = \frac{\sigma_t}{E} - \nu\frac{\sigma_r}{E}$$

$$\text{Radial strain} = \frac{d\xi}{dx} = \frac{\sigma_r}{E} - \nu\frac{\sigma_t}{E}$$

$$\text{Hence} \quad \sigma_r = \frac{E}{1-\nu^2}\left(\frac{d\xi}{dx} + \nu\frac{\xi}{x}\right) \quad (1)$$

$$\sigma_t = \frac{E}{1-\nu^2}\left(\frac{\xi}{x} + \nu\frac{d\xi}{dx}\right) \quad (2)$$

By considering the radial equilibrium of the element of volume shown in fig. 1, we get :—

$$x\delta\theta\delta x y\mu\omega^2 x + \frac{d}{dx}\left(\sigma_r y x\right)\delta x\delta\theta - \sigma_t y\delta x\delta\theta = 0$$

to the second order of infinitesimals,

$$i.e., \quad x^2 y\mu\omega^2 + \frac{d}{dx}\left(\sigma_r y x\right) - \sigma_t y = 0 \quad . \quad (3)$$

Substituting $y = Cx^{-\alpha}$ and for σ_r, σ_t from (1) and (2), equation (3) becomes on simplification

$$x^2\frac{d^2\xi}{dx^2} + \left(1-\alpha\right)x\frac{d\xi}{dx} - \left(\alpha\nu+1\right)\xi = -Ax^3 \quad (4)$$

where $A = \dfrac{(1-\nu^2)\,\mu\,\omega^2}{E}$

Solving this equation in the normal manner we get :—

$$\xi = a x^3 + b_1 x^{\psi_1} + b_2 x^{\psi_2} \quad . \quad . \quad . \quad . \quad (5)$$

where

$$a = -\frac{A}{[8-(3+\nu)\alpha]},$$

$$\psi_1 = \frac{\alpha}{2} + \sqrt{\frac{\alpha^2}{4} + \alpha\nu + 1},\ \psi_2 = \frac{\alpha}{2} - \sqrt{\frac{\alpha^2}{4} + \alpha\nu + 1}$$

b_1 and b_2 are arbitrary constants whose values are determined by the boundary conditions, *i.e.*, the conditions at the junction of the profile with the boss and rim.

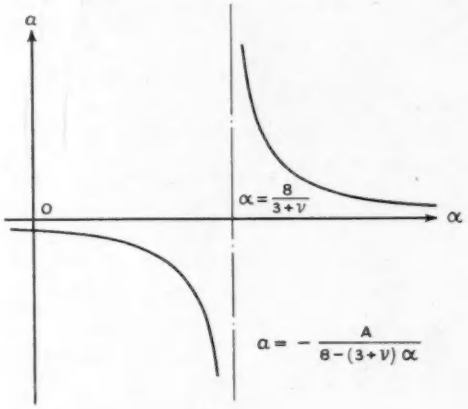


Fig. 2

Substituting for ξ in equations (1) and (2) we get the usual Stodola stress equations

$$\sigma_r = \frac{E}{1-\nu^2}\Big[(3+\nu)\,a x^2 + (\psi_1+\nu)\,b_1 x^{\psi_1-1} + (\psi_2+\nu) b_2 x^{\psi_2-1}\Big] \quad . \quad (6)$$

$$\sigma_t = \frac{E}{1-\nu^2}\Big[(1+3\nu)\,a x^2 + (1+\psi_1\nu)\,b_1 x^{\psi_1-1} + (1+\psi_2\nu) b_2 x^{\psi_2-1}\Big] \quad . \quad (7)$$

These equations become incommensurable if the profile has a "critical taper," *i.e.*, if $8-(3+\nu)\,\alpha = 0$, for an infinite discontinuity occurs at this value of α on the curve

$$a = -\frac{A}{8-(3+\nu)\,\alpha} \quad \text{(see fig. 2).}$$

For $\nu = 0{\cdot}3$, the value of α in question is $\dfrac{8}{3{\cdot}3}$ or 2.42 approximately and wheels with profiles having this value of α sometimes occur in practice. The difficulty may be overcome in the following manner, which the writer believes to be novel.

We consider the differential equation (4), *i.e.*,

$$x^2\frac{d^2\xi}{dx^2} + (1-\alpha)x\frac{d\xi}{dx} - (\alpha\nu+1)\xi = -Ax^3$$

We change the independent variable to θ where $x = e^{\theta}$ so that $\dfrac{d\theta}{dx} = \dfrac{1}{x}$, and the equation transforms to

$$\frac{d^2\xi}{d\theta^2} - \alpha\frac{d\xi}{d\theta} - (\alpha\nu+1)\xi = -Ae^{3\theta} \quad . \quad . \quad (8)$$

or $\Big[D^2 - \alpha D - (\alpha\nu+1)\Big]\,\xi = -Ae^{3\theta}$

where D represents the operator $\dfrac{d}{d\theta}$

The auxiliary equation of (8) is

$$\psi^2 - \alpha\psi - (\alpha\nu+1) = 0$$

with roots

$$\psi_1 = \frac{\alpha}{2} + \sqrt{\frac{\alpha^2}{4} + \alpha\nu + 1}$$

$$\psi_2 = \frac{\alpha}{2} - \sqrt{\frac{\alpha^2}{4} + \alpha\nu + 1}$$

We note here that if $8-(3+\nu)\,\alpha = 0$,

$$\psi_1 = 3,\ \psi_2 = -\frac{1+3\nu}{3+\nu}$$

The complementary function of (8) is then

$$\xi = b_1 e^{\psi_1\theta} + b_2 e^{\psi_2\theta}$$

The particular integral is

$$\xi = \frac{1}{D^2 - \alpha D - (\alpha\nu+1)} \cdot -Ae^{3\theta},$$ the normal solution being $\xi = -\dfrac{A}{[8-(3+\nu)\alpha]} \cdot e^{3\theta}$ by substituting $D=3$, and this fails if $8-(3+\nu)\alpha = 0$. For this case we take

$$\xi = \frac{1}{D^2 - \alpha D - (\alpha\nu+1)} \cdot -Ae^{3\theta}$$

and use the fact that

$$f(D)\,e^{n\theta}\,\varphi(\theta) = e^{n\theta} f(D+n)\varphi(\theta).$$

(See *e.g.*, Differential Equations, Piaggio, Revised Ed. Art. 32 and 35).

Hence $\xi = -Ae^{3\theta} \dfrac{1}{(D+3)^2 - \alpha(D+3) - (\alpha\nu+1)} \cdot 1$

since here $\varphi(\theta) = 1$.

$$i.e., \xi = -Ae^{3\theta}\frac{1}{(6-\alpha)D+D^2}\cdot 1$$

$$= -Ae^{3\theta}\left[\frac{1}{(6-\alpha)D}-\frac{1}{(6-\alpha)^2}+\frac{D}{(6-\alpha)^3}\cdots\right]\cdot 1$$

$$= -Ae^{3\theta}\left[\frac{\theta}{(6-\alpha)}-\frac{1}{(6-\alpha)^2}\right] \quad \ldots \quad (9)$$

Now if $8-(3+\nu)\alpha = 0$, $\psi_1 = 3$, so that the complementary function contains a term in $e^{3\theta}$ and we may omit the second bracketed term in (9).

The particular integral of (8) is then

$$\xi = -\frac{A}{(6-\alpha)}\theta e^{3\theta}$$

and the complete solution is

$$\xi = -\frac{A}{(6-\alpha)}\theta e^{3\theta} + b_1 e^{\psi_1\theta} + b_2 e^{\psi_2\theta}.$$

Changing the independent variable to x we get

$$\xi = -\frac{A}{(6-\alpha)}x^3\log_e x + b_1 x^{\psi_1} + b_2 x^{\psi_2} \quad . \quad (10)$$

This is the strain equation and from equations (1) and (2) the corresponding stress equations are

$$\sigma_r = \frac{E}{1-\nu^2}\left[-\frac{A}{(6-\alpha)}\left\{1+(3+\nu)\log_e x\right\}x^2 + (\psi_1+\nu)b_1 x^{\psi_1-1} + (\psi_2+\nu)b_2 x^{\psi_2-1}\right] \quad (11)$$

$$\sigma_t = \frac{E}{1-\nu^2}\left[-\frac{A}{(6-\alpha)}\left\{\nu+(1+3\nu)\log_e x\right\}x^2 + (1+\psi_1\nu)b_1 x^{\psi_1-1} + (1+\psi_2\nu)b_2 x^{\psi_2-1}\right] \quad (12)$$

and we note that

$$\psi_1 = 3, \ \psi_2 = -\frac{1+3\nu}{3+\nu}.$$

It might be argued that if the above case were met with in practice the profile of the disc could be altered slightly so that $8-(3+\nu)\alpha$ would not be zero, but it is advantageous, in fact advisable, to use the above special solution, which is no more difficult to compute than the normal case, for the following reason :

If $8-(3+\nu)\alpha$ is small, the term containing $a = -\frac{A}{8-(3+\nu)\alpha}$ in equations (5), (6) and (7) is large and the remaining terms containing b_1 and b_2 must be correspondingly large. The algebraical sum of the three terms in each of the equations gives the required extension or stress at any point, but since the terms are large numerically compared with the stress, a high order of arithmetical accuracy must be maintained throughout the calculation. If the above special solution is used, the term containing A and the sum of the remaining terms in any equation will be of the same order of magnitude.

This point is illustrated by a simplified numerical example :

Taking $\omega = 100\pi$ rad/sec.

$E = 30 \times 10^6$ lb/sq. in.

$\nu = 0{\cdot}3$

$\mu = \frac{0{\cdot}283}{386{\cdot}4}$ lb. in.$^{-4}$ sec.^{2}

$\alpha = 2{\cdot}4$

The first term in equation (6), *i.e.*,

$$\frac{E}{1-\nu^2}(3+\nu)\,a\,x^2$$

becomes, for $x = 20$in., $-0{\cdot}1193\times10^7$ lbs./sq. in.

The radial stress σ_r would here be about 20,000 lbs./sq. in. for a normal wheel, so that to calculate the stress to within 100 lbs./sq. in., taking into account the arithmetical complication of the simultaneous equations for determining b_1 and b_2, six figure accuracy would be necessary throughout.

For $\alpha = 2{\cdot}42$, $8-3{\cdot}3\,\alpha = 0$ so that by the special method, the 1st term of equation (11) is

$$-\frac{E}{1-\nu^2}\cdot\frac{A}{6-\alpha}\left\{1+(3+\nu)\log_e x\right\}x^2$$

and for $x = 20$in. this becomes

$$-0{\cdot}877\times10^5 \text{ lbs./sq. in.}$$

which is of the same order of magnitude as σ_r at this point. Four figure accuracy would here be sufficient to calculate the stress to 100 lbs./sq. in.

Electrical Equipment in a Modern Rubber Mixing Plant

By F. W. HAYES, D.C.M., A.M.I.E.E.,
Branch Engineer, Birmingham.

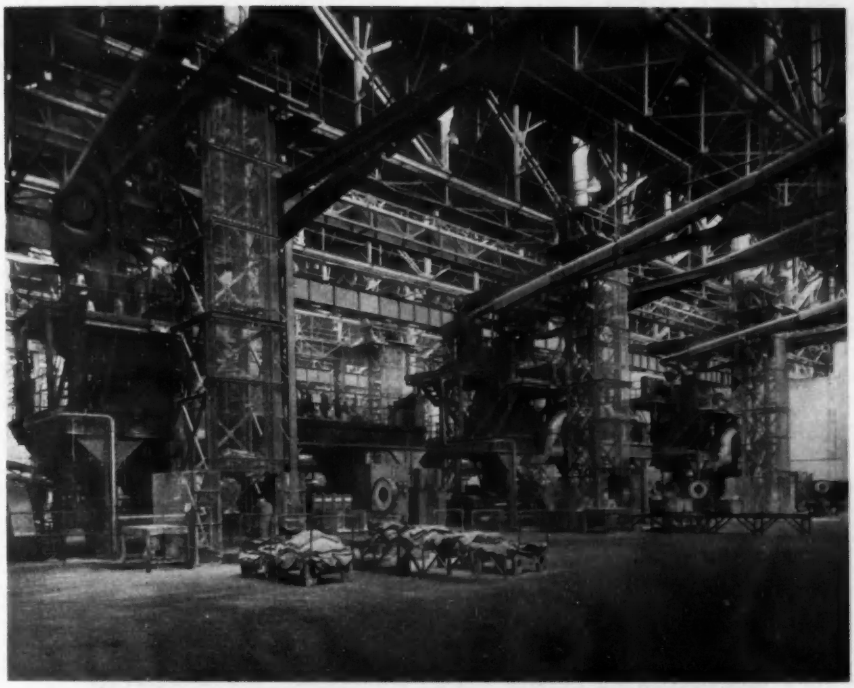


Fig. 1.—A bank of Bridge-Banbury mixers with elevators and enclosed powder conveyors.

INTRODUCTION.

ANTICIPATING the demand for rubber products which would certainly follow the termination of hostilities, the Dunlop Rubber Co. Ltd. concluded arrangements with the Government under which the Company took over, on August 1st, 1945, a very large aircraft factory at Speke, near Liverpool, which had been operated by Rootes Securities Ltd. on behalf of the Ministry of Aircraft Production. The area of the site is 101 acres, on which buildings covering 1,400,000 square feet are erected.

Under the difficult conditions prevailing in the period following the war, it was no simple task to convert a factory of this size, designed for the production of aircraft under wartime conditions, into a plant for rubber processing and the manufacture of rubber products to meet peacetime demands. The combination of thought and careful planning, however, has resulted in a factory which must be regarded as a model of its kind and one in which everything has been provided to ensure a smooth and efficient flow of production. It is believed that this is the first example of rubber processing and manufacture proceeding in one straight flow line throughout a factory.

ARRANGEMENT OF PLANT.

The main building is 1,440 feet long and 600 feet wide, with building heights of 20 feet, 30 feet and 40 feet, from south to north. This, as will be explained later, rendered the building suitable for a north-to-south flow-line.

In addition to the rubber mixing and milling plant, the main building also houses equipment for the production of tyres and tubes, rubber footwear and tennis and golf balls. Other buildings on the site include a precision components and saddle works, a large belting shop, extensive raw material stores, boiler house, power house, canteen, offices, and so on, the whole constituting a spacious, yet convenient, layout.

TREATMENT OF THE RAW MATERIAL.

Rubber as received from the plantation requires considerable processing before it is in a suitable condition for commercial use. The present article deals with these early stages of manufacture, from the mixing of the raw rubber with other ingredients and the milling of the compound until finally it emerges in the form of rubber sheeting of one or other of the various types required for the manufacture of the Company's many products. A description will also be given of the machines employed in these mixing and milling processes.

PREPARATION FOR MIXING.

The first stage in the preparation of the rubber compound takes place in a specially designed powder room at the extreme north of the building. The nature of certain of the ingredients, notably gas and lamp black, renders it essential that the means for weighing and measuring, as well as for conveying them to the mixing machines some 50ft. away, shall be totally enclosed, as can be seen by reference to fig. 1, in order to ensure cleanliness for the workers and in the shops.

The totally enclosed conveyor, of the caterpillar type, is electrically driven and is automatically controlled from a central panel on the operator's platform. The conveyor delivers the powder into the hopper of a weighing machine, the speed of the conveyor being reduced automatically when nearing the final weight to ensure accurate weighing of the charge to the pre-determined requirements. This control of the drive is effected by means of a solenoid-operated clutch.

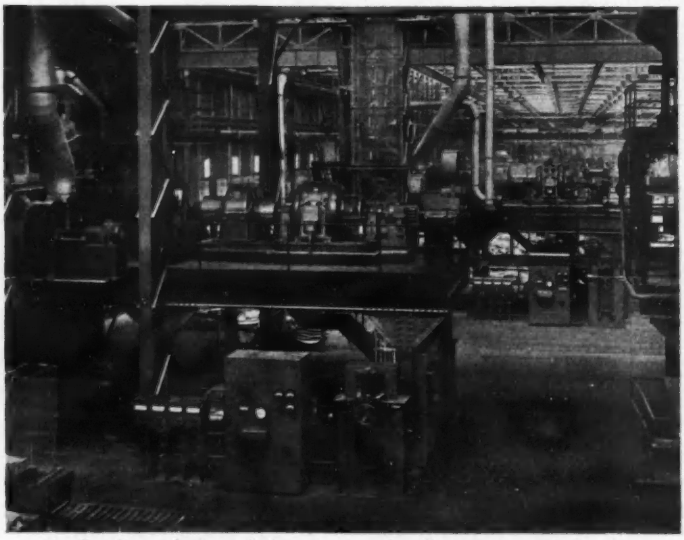


Fig. 2.—General view of the mixing and milling sections of the shop as seen from the north end.

BRIDGE-BANBURY MIXING MACHINES.

Mixing of the powders and other solid ingredients with the raw rubber itself takes place in a number of Bridge-Banbury mixing machines. These machines, a battery of which is shown in fig. 1, are of considerable interest. Impressive in design and appearance, they rise to a height of 35 feet above floor level and

perform a series of complex operations with great accuracy and with a minimum of manual or supervisory labour. Control of such operations as weighing, timing and temperature regulation is almost entirely automatic and is combined with an efficient signalling system whereby the operator is kept fully informed as to the progress of the various stages in the cycle of operation.

The weighing hopper into which the conveyor just described delivers the powder is situated at the top working level of the machine. The weighed powder is discharged into the loading hopper immediately below the weighing equipment. To this level are brought other ingredients of a more solid nature, by means of an electrically driven elevator which runs the whole height of the machine (see fig. 1). The powder and other ingredients are next discharged into the mixer proper which, with its electric motor, is situated on the main platform immediately below the loading hopper (figs. 2 and 3). At the same time the elevator will have brought to the mixing chamber level a charge of the correct weight of raw rubber. The raw rubber and all the ingredients are then thoroughly mixed, the duration of the mixing process, the temperature of the mix and other factors depending on the specification for the rubber which is being produced.

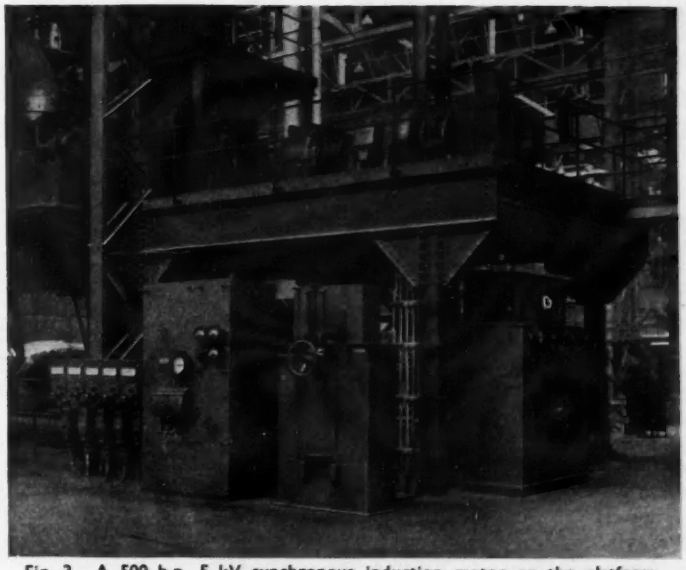


Fig. 3.—A 500 h.p. 5 kV synchronous induction motor on the platform driving one of the Bridge-Banbury mixers. The stator control gear and liquid starter are mounted on the floor below. A bank of 5 kV ring main isolators is seen to the left of the stator panel. The contactor cubicle on the right controls one of the 125 h.p. 400 volt mill motors.

Milling.

When mixing is complete, the mixture is discharged through a chute to the rolling mill (fig. 4) which, with its motor, is on the floor level immediately beneath (fig. 5). Here it undergoes repeated rolling and milling, finally emerging in the form of rubber sheet.

Mixed and sheeted rubber is taken away from certain of the mixing units on a G.E.C. overhead chain conveyor. The carriers, which are of tubular construction, each take two sheets of rubber and, after collecting from the mills in the circuit, pass through a spray tank and climb to the underside of the roof members, 35 ft. from the floor.

The conveyor travels backwards and forwards in gridiron formation at this height and is of sufficient length to afford the time necessary for cooling before it descends again to a suitable height at which the rubber sheets can be taken off at the binning area.

The total length of the conveyor is approximately 1,900 ft., and it is fitted with two synchronised motor drives and suitable tensioning units so arranged as to distribute the load evenly on the conveyor chain.

Further treatment of the sheeted rubber compound depends on the grade required and the products for which it is destined to form the raw material. Additional milling is carried out on other mills along the production line (fig. 6) with the object of warming or softening the compound for subsequent processing in calenders, extruders, and so forth.

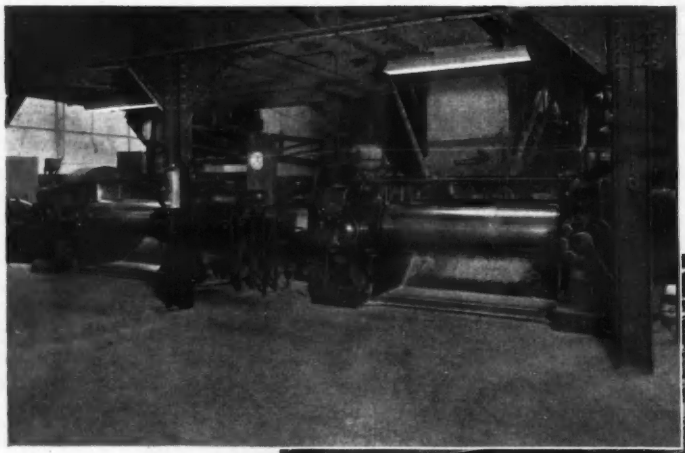


Fig. 4 (*left.*)—Two 84 inch open roll mills driven by a 300 h.p. 5 kV synchronous induction motor. The illustration also shows the inter-mill conveyor and the emergency stop trip cord along the front of the machines.

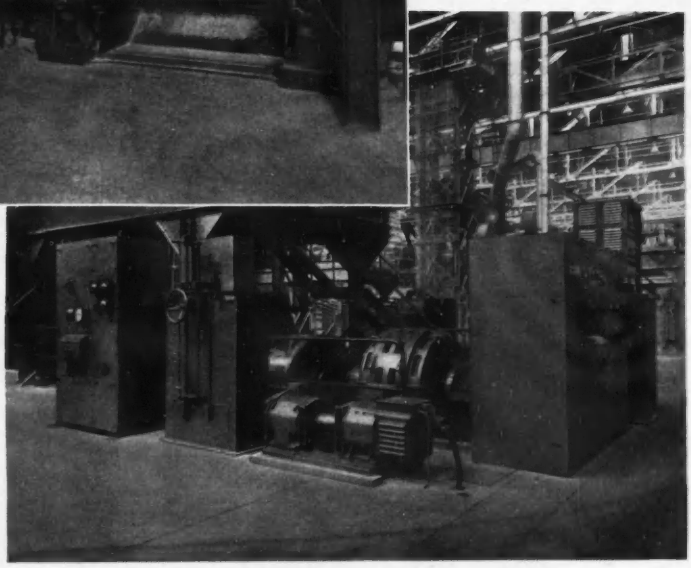


Fig. 5 (*right*).—The 300 h.p. 5 kV mill motor, with separate motor generator exciter set, driving the 84 inch rolls seen in fig. 4. On the right are the starting and control panels together with the starting and braking resistances.

LAYOUT AND ELECTRICAL EQUIPMENT.

Extension of Supply System.

In planning the layout of the new Works, it was necessary, on account of the height of the Bridge-Banbury mixers, to erect them at the north end of the building where the headroom is greatest. This arrangement determined the flow of production as from north to south, which is the reverse of the direction of the original aircraft flow line. It also called for the heaviest demand on the power supply at the north end and the whole distribution system was based on this consideration. It was realized, also, that considerably more power would be required, the consumption for rubber processing being about 7·5 times as much per sq. foot of working area as for aircraft construction. The Liverpool Corporation Electricity Department therefore arranged to provide two new 11 kV feeders, and a new substation was equipped to handle this additional supply. The substation was located near the north end of the building so as to be as close as possible to the heaviest load. Similar arrangements were made with regard to water and process steam, the pump room and the boiler house being nearer the south end where the demand for these services is greatest.

Electrical Equipment.

Three additional 11 kV/5 kV, 1,500 kVA, transformers were supplied by The General Electric Company Ltd., who also supplied the new 11 kV and 5 kV main switchboards; the whole of the 7,200 h.p. of 5 kV motors,

ran[illegible] from 300 to 600 h.p., and their control gear, for the Bridge-Banbury mixers and certain of the mills; the isolator equipment for the 5 kV ring mains; and more than 4,300 h.p. in 400 volt motors, rated from 100 to 350 h.p., with their control gear, for driving mills and other machines. Numerous smaller motors for a variety of purposes were also supplied. In addition, the contracts included the application of dynamic braking to all mill motors and the provision of the separate motor-generator exciter sets for these motors.

11 kV and 5 kV Distribution Systems.

The new 11 kV supply is taken to a 7-panel truck type cubicle switchboard (fig. 7), comprising two incoming feeder panels, three transformer panels, a transformer substation feeder panel and a bus coupler panel for linking up with either section of the 11 kV system in case of a breakdown. Each of the two incoming feeder panels is equipped with a 250 MVA rupturing capacity, 400 amp. oil circuit breaker, three single-pole directional overload relays, ammeter, voltmeter, watthour meter and power factor indicator, with the usual instrument transformers and shunt trip. The three outgoing 1,500 kVA transformer panels and the outgoing transformer substation panel carry an oil circuit breaker, a 3-pole directional overload relay, a single-pole earth leakage relay and the usual measuring instruments and their transformers. The bus coupler unit is equipped with an oil circuit breaker as above, but is non-automatic. The transformer substation, which is fed from the panel described above, is located in a remote position in the belting department and is equipped with a truck cubicle containing incoming and outgoing cable boxes, an oil circuit breaker as above, a 3-pole overload relay, measuring instruments and transformers.

From the 11 kV board the supply is taken to three 11 kV/5 kV, 1,500 kVA transformers which are located outside the substation. The 5 kV output of these transformers is fed to a 9-panel truck cubicle switchboard located in the same substation. This board (fig. 7) comprises three transformer panels, four ring feeder panels, one busbar section switch panel and a spare panel for a fourth transformer. Each panel is equipped with a 150 MVA, 400 amp. oil circuit breaker. The three incoming feeder panels also carry three single-pole directional overload relays, a single-pole earth leakage relay and the necessary instruments and transformers. The four outgoing units to the ring mains are equipped with oil circuit breaker, 3-pole overload relay,

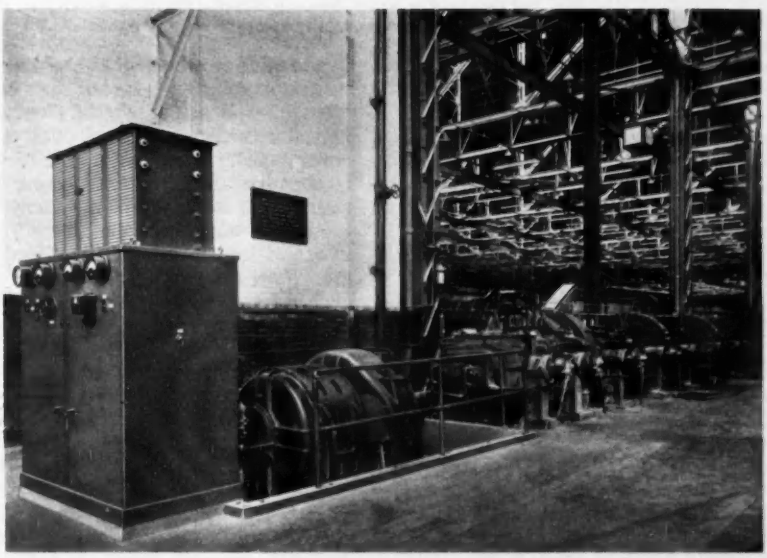


Fig. 6.—A 300 h.p. 400 volt synchronous induction motor driving 60-inch open roll and breaker type mills. On the left can be seen the control gear and the resistances for dynamic braking. The emergency trip cord is shown along the front of the machines.

single-pole earth leakage relay and instruments. The bus section switch unit is provided with a non-automatic oil circuit breaker and two voltmeters. Two withdrawable 3-phase voltage transformers are mounted above the cubicles.

Distribution from this switchboard is by two sets of ring mains, each feeding a section of the mixing, calendering and extruding departments. Adjacent to positions where a motor or a group of motors is to be driven, the ring main is looped by means of a totally enclosed 5 kV 400 amp. oil-immersed isolator for each circuit. These isolators can be seen on the left of the illustrations in figs. 2 and 3. These are so connected that when the case is opened the cable is earthed. There are 37 of these isolators mounted in groups of 3 to 5 isolators in each.

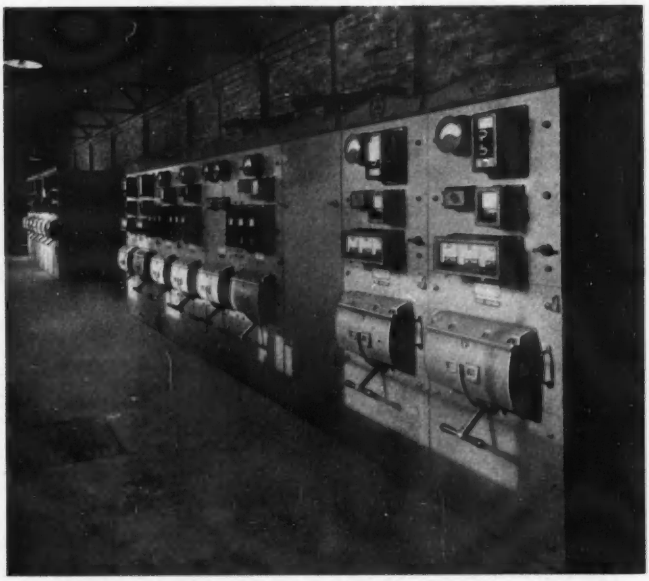


Fig. 7.—The new substation showing the 7-panel 11 kV truck type cubicle switchboard and, in the foreground, the 9-panel 5 kV cubicle board.

ELECTRIC DRIVES AND CONTROLS.

Bridge-Banbury Mixers.

Each of the Bridge-Banbury mixers is driven by a 500 h.p., 5 kV. 750 r.p.m. synchronous induction motor (fig. 3), operating at 0.9 leading power factor. These motors have been designed to withstand the heavy peak loads likely to be encountered in rubber mixing. Both the starting and the pull-out torque are 2.5 times full load torque. The motor speed of 750 r.p.m. is reduced to 30 r.p.m. on the mixer shaft by means of reduction gearing with an overall ratio of 25 : 1. The exciters are direct-coupled.

In general, the controls for these motors follow standard practice, the free-handle oil circuit breaker being fitted with two overload releases and oil time-lag dashpots and a single-pole direct-acting earth-leakage trip. The stator control cubicle also houses an interlocked combined isolating and off-load reversing switch. A fully interlocked three-electrode liquid starter regulates the rotor-circuit current.

Open Roll Mills.

The mills are driven, independently or in batteries, by synchronous induction motors of 600, 300 or 125 h.p. according to the duty required. The 600 h.p. and some of the 300 h.p. mill motors are supplied at 5 kV, the remainder of the 300 h.p. and the 125 h.p. motors being fed at 400 volts.

Mill Motors.

The motors, which are designed to handle heavy overloads, operate at 375 r.p.m. and 0·9 leading power factor at which value it can be maintained by means of the field regulator. The drive is through totally enclosed double helical reduction gearing. The whole of the control gear, which is of the air-break contactor type with separate starting and braking resistances, is housed in the control cubicle.

As the mill motors are equipped with dynamic braking—which is described later—the rotors are of low inertia to assist rapid deceleration and stopping. The exciters for these motors are separate motor-driven sets (fig. 5), so that excitation may be maintained after the main circuit breaker or contactor has been tripped, thus providing the over-excitation which is an essential feature of the braking system.

Motor Controls.

The following description of the control gear for these motors also explains the application of dynamic braking. References are to the typical schematic diagram shown in fig. 8.

When the motor of the motor-generator set

is started in the usual manner from its own push-button direct-to-line starter, the latch-in "brake" contactor is first operated. This disconnects the braking resistances from the synchronous motor primary circuit. Interlock contacts on the latch-in contactor make the

tained by adjusting the D.C. excitation of the mill motor.

Dynamic Braking.

For emergency stopping of the mill motor a weight-operated ironclad trip switch, with

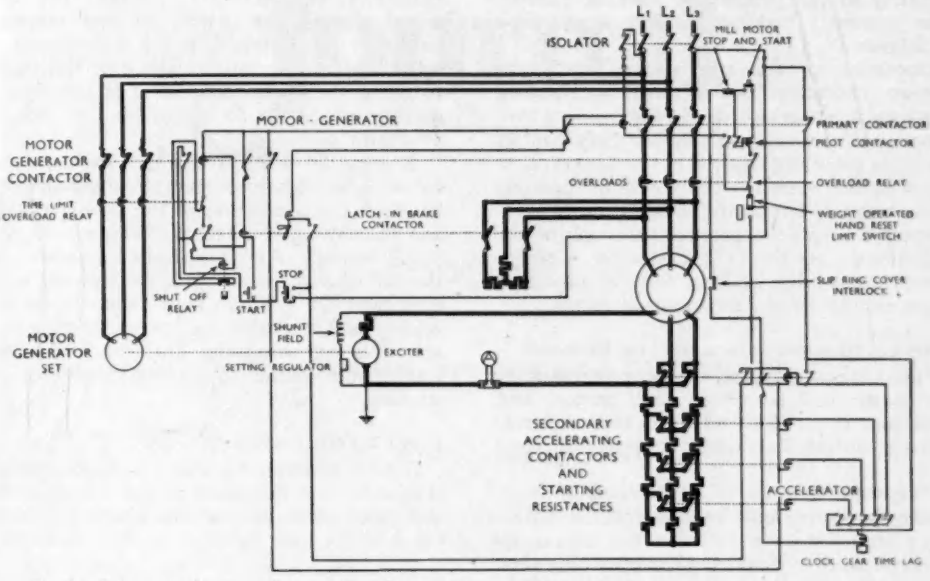


Fig. 8.—Schematic diagram of connections for synchronous induction motor control and dynamic braking.

closing circuit for the motor-generator stator contactor. Interlocks on the motor-generator contactor are connected in the operating coil circuits of the mill motor primary contactor thus ensuring that the motor-generator set shall always be running before the mill motor can be started. On the 5 kV equipments the primary contactor is replaced by a manually operated oil circuit breaker. The inter-locking and braking circuits are identical with those for the 400 volt equipments which are here described.

The mill motor start push-button closes the pilot contactor, which in turn closes the primary contactor. An interlock in the latter completes the time-controlled accelerator circuit, the timing element being a very substantial clock gear which controls the closing of a series of secondary accelerating contactors, these finally short circuiting the starting resistance and allowing the mill motor to run up to full speed.

The required power factor is ob-

trigger latch release and hand closing mechanism, is coupled to a trip wire running along the working faces of the mill within easy reach of the operator (figs. 4 and 6). The slightest touch on this trip wire suffices to stop the mill motor in about 3.5 revolutions of the motor shaft that is after the roller has travelled only about 6.5 to 8.5 inches measured

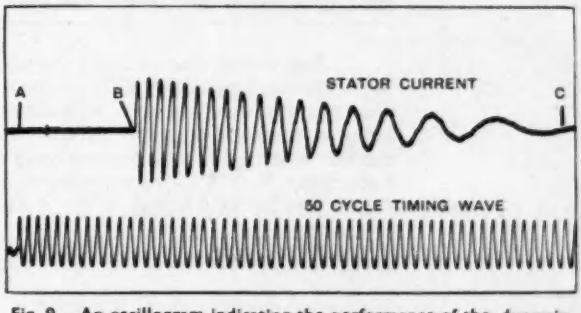


Fig. 9.—An oscillogram indicating the performance of the dynamic braking equipment on a 600 h.p., 5 kV synchronous induction motor from the moment of pulling the emergency trip cord until the motor is brought to rest.

along its periphery. In most cases the actual distance is even less when the mills are loaded with rubber which exerts a powerful resistance to the rotation of the rolls, and thus the initiation of dynamic braking by means of a trip cord provides the greatest possible degree of safety in the process of working rubber. The dynamic braking feature is obtained as follows :

Operation of the trip switch opens the primary contactor, but the final accelerating contactor remains closed. As the primary contactor opens, an early closing auxiliary contact energises the shunt trip coil of the latch-in contactor, so that simultaneously with the opening of the primary circuit the braking resistance is connected across the primary terminals of the mill motor. As the D.C. excitation is maintained, a powerful braking force is produced which rapidly brings the motor to rest.

Dynamic Braking—Oscillogram Records.

Fig. 9 shows a typical oscillogram taken on one of the 600 h.p. 5 kV mill motors and illustrates the effectiveness of this dynamic braking system in rapidly stopping a large motor

The total number of revolutions through which the rotor will rotate after the emergency cord has been pulled is the sum of its revolutions, A to B, during the operating time of the contactor gear and the revolutions, B to C, after braking has been applied. From the oscillogram, it is seen that A to B represents 12 cycles and, as the motor has eight pairs of poles, this is equivalent to $12 \div 8 = 1{\cdot}5$ revolutions of the rotor. The braking revolutions, B to C, are measured by the number of cycles induced in the secondary (stator) circuit, *i.e.*, the number of pairs of poles which pass any one point on the stator. As shown on the oscillogram, this number is 17, so that the revolutions of the rotor during the braking period is $17 \div 8 = 2{\cdot}13$. Thus, the total travel during the whole of the stopping period, A to B + B to C, is $1{\cdot}5 + 2{\cdot}13 = 3{\cdot}63$ revolutions of the rotor. The total time taken to bring the motor to rest is shown by the oscillogram to be 53 cycles or 1·06 sec. at 50 cycles per second.

It may be added that the latch-in contactor is so designed that the time elapsing between the energizing of the shunt trip coil and the closing of its main resistance is only 0·031 second. Approximately 5 seconds after the mill motor has stopped, the shut-off relay, energised by the auxiliary contacts on the brake contactor, trips out the motor-generator set, thus removing the D.C. excitation and leaving the whole equipment ready for re-starting.

Plant for New Zealand.

A point of interest is that G.E.C. equipment similar to that described in the foregoing has also been ordered by the Dunlop Rubber Co. Ltd. for their factories in New Zealand.

Acknowledgments.

In conclusion the author wishes to acknowledge the kind permission of Dunlop Rubber Co., Ltd. to publish this article.

THE ASSOCIATION OF SHORT CIRCUIT TESTING AUTHORITIES

The Association of Short Circuit Testing Authorities, 36, Kingsway, London, W.C.2, of which The General Electric Co. Ltd., is a member, has re-issued its publication No. 1, being a description of the various circuit breaker testing stations existing in this country, and has issued a further publication, No. 10, being a comparison between British and U.S.A. short circuit ratings.

Copies of these publications can be obtained on application to A.S.T.A. at the above address.